PATENT

Attorney Docket No. SIC-03-024

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

In re application of:

KOUJI OOHARA

Application No.: 10/604,813

Filed: August 19, 2003

For: POWER STABILIZING APPARATUS FOR A BICYCLE ELECTRICAL COMPONENT

Examiner: Dru M. Parries

Art Unit: 2836

APPEAL BRIEF

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

This is an appeal brief for the above-captioned matter.

I. Real Party In Interest

The assignee and real party in interest is Shimano, Inc., a Japanese corporation having a principal place of business in Osaka, Japan.

II. Related Appeals And Interferences

There are no prior or pending appeals, interferences or judicial proceedings known to the appellant, to appellant's legal representative, or to the assignee which may be related to, directly affect, or be directly affected by, or have a bearing on the Board's decision in the pending appeal.

III. Status Of Claims

Claims 28-48 are pending under final rejection and are under appeal. Claims 1-27 have been canceled.

IV. Status Of Amendments

No amendment was filed subsequent to final rejection.

V. Summary Of Claimed Subject Matter

The application discloses an apparatus for stabilizing power to a bicycle component. Cited reference numbers and text are examples only and are not intended to be limiting. Line numbers refer to the line numbers within each individually cited paragraph.

As applied to independent claim 28, a bicycle electrical control apparatus comprises:

a programmed power/control circuit ((35), Fig. 3, page 4, paragraph [0015], lines 1-2) that receives power from a power supply ((19), Fig. 3, pages 3-4, paragraph [0014], lines 7-9) and outputs a composite signal having a power signal component and a control signal component (pages 4-5, paragraph [0016], lines 1-3), wherein the control signal component contains information such that the composite signal can be decoded to extract the information contained in the control signal component (pages 4-5, paragraph [0016], lines 4-7);

a first electrical bicycle component ((55), Fig. 3, page 5, paragraph [0018], lines 1-3) that receives the composite signal and is controlled by the information contained in the control signal component of the composite signal (pages 4-5, paragraph [0016], lines 4-7);

a second electrical bicycle component ((58), Fig. 3, page 5, paragraph [0018], lines 2-3) that receives the composite signal but is not controlled by the control signal component of the composite signal (page 6, paragraph [0021], lines 5-11); and

a power stabilizing circuit ((57), page 5, paragraph [0018], lines 2-3) that receives the composite signal, stabilizes power provided from the composite signal, and provides stabilized power to the second electrical bicycle component (page 6, paragraph [0021], lines 11-14).

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VI. Grounds of Rejection to be Reviewed on Appeal

Claims 28-32, 34-39, 42-46 and 48 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Spencer, et al (US 6,047,230) in view of Schwaller (US 5,247,430) and an admission as to the state of the prior art.

Claims 33 and 47 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Spencer, et al, Schwaller and admitted prior art in view of and Gohda (US 4,609,982).

Claim 40 stands rejected under 35 U.S.C. §103(a) as being unpatentable over Spencer, et al, Schwaller and admitted prior art in view of and Tomita (JP 07-229,909).

Claim 41 stands rejected under 35 U.S.C. §103(a) as being unpatentable over Spencer, at al, Schwaller and admitted prior art in view of Turner (US 2002/0014366).

VII. Argument

Rejection under 35 U.S.C. §103(a) over Spencer, et al (US 6,047,230) in view of Schwaller (US 5,247,430) and admitted prior art.

Claims 28-32, 34-38, 42-46, and 48

Spencer, et al discloses an automatic bicycle transmission wherein a controller (21) receives power from a power supply (30) and receives information signals from various input components (e.g., 23-28 and 32-33). Controller (21) processes the signals from the various input components and determines when to provide signals to a shifter motor (29) that changes gears in the bicycle transmission. Controller (21) also provides signals to a display (31) that displays various information.

Schawaller discloses a bicycle lighting system wherein a switching controller ((1), Figs. 1 and 2) regulates the voltage from an alternating current generator (G) and provides the regulated voltage to lamps R_L and V_L. As shown in Fig. 2, switching controller (1) uses an oscillator (11) and an operational amplifier (4) to produce ON/OFF pulses having the variable duty-ratio shown in Fig.

3. An L-C circuit shown in Fig. 2 and described at column 3, lines 53-54 is used to convert the pulses into a direct current signal supplied to lamps R_L and V_L.

The Appellant states at page 1, paragraph [0003], lines 1-3 of the specification that technology for communicating power and control signals using integrated or composite signals has been developed to reduce the number of wires required between the various electrical components. That statement constitutes the admitted prior art.

Page 5, second paragraph, of the final office action dated February 6, 2008 alleges that it would have been obvious to one of ordinary skill in the art at the time of the invention to use composite signals throughout Spencer, et al's bicycle system to reduce the number of wires used around the bicycle and/or to add more versatility to the bicycle by having the ability to send both power and control signals on the same wire.

Rejections on obviousness cannot be sustained by mere conclusory statements; instead, there must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness. *KSR International Co. v. Teleflex Inc.* 550 U.S. __, 82 USPQ2d 1385, 1396 (2007). Two reasons were offered to support the incentive to modify the Spencer, et al system: (1) to reduce the number of wires used around the bicycle, and (2) to add more versatility to the bicycle by having the ability to send both power and control signals on the same wire.

Reason (1) – to reduce the number of wires used around the bicycle - is a *non sequitur*. A wire reduction occurs only with prior art devices that use both power and control signals. More specifically, such devices require at least two wires: one wire for the power signal and one or more wires for the control signal(s). Using a composite signal allows such devices to be powered and controlled using a single wire. However, devices that do not use control signals use only one wire to begin with - a power wire. Lamps and other non-controlled devices (i.e., devices that operate simply by the application of operating power) do not use control signals. Thus, there is no reason to power non-controlled devices with a composite signal to save wires because there are no wires to be saved with such devices.

Reason (2) - to add more versatility to the bicycle by having the ability to send both power and control signals on the same wire – is further discussed by the examiner at pages 2-3 of the office action.

Initially, the Appellant wants to clarify a statement made at the last paragraph of page 2 of the office action. The office action states that Spencer, et al's system (Fig. 2) teaches all power and control signals flowing out of controller (21). However, it must be noted that the power and control signals flowing from Spencer, et al's system (Fig., 2) are not composite signals having a power signal component and a control signal component, wherein the control signal component contains information such that the composite signal can be decoded to extract the information contained in the control signal component (as recited in claim 28).

Second, the Appellant disputes a factual statement made at the last paragraph of page 2 of the office action. The office action refers to "the backlight of Spencer's display (31)." However, it is clear from the pinouts for the AND711AST display shown in Figs. 11 and 14 that there is no backlight in the Spencer, et al system.

Standard liquid crystal displays typically comprise an LCD display screen with associated electronics, a polarizer film (which tends to add a green tint to the display), and a reflective backing (which tends to add a silver or gray tint to the display). When a backlight is added, the reflective backing is removed, and the backlight in the form of an electro-luminescent (EL) device (such as an electro-luminescent foil or an LED) is substituted for the reflective backing. The EL device is supplied with power, usually designated V_{EL}. As seen from the pinouts in Figs. 11 and 14 of Spencer, et al, the LCD display is provided with standard LCD segment illumination lines LCD (0-7), a separate power supply line (LCDDRV) for the LCD drive (usually called V_{EE}), a separate data write line (LCDCD), a separate chip enable line (LCDCE), a separate command/data/status read/write line (LCDWR), a separate reset line (DRESET), a separate ground line (GND), and a separate VCC line to pull up the signals to the data read pin (display pin (6), Fig. 14) and the font select pin (display pin (19), Fig. 14). There is no V_{EL} pin or V_{EL} signal line, which would be present if the disclosed AND711AST display had a backlight, so there is no backlight.

In any event, page 3, first paragraph, of the office action alleges that one of ordinary skill in the art would want to use composite signals throughout Spencer, et al's system and to supply those composite signals to devices that do not use both the power and control components of the composite signals because it is possible that the device that does not use both power and control signals may be removed from the system in the future and replaced by a device that *does* use both power and control signals. According to the office action, the benefit of providing composite signals to a component that does not use composite signals is to have the "composite wire" already installed for the hypothetical future modification.

First, there is no such thing as a "composite wire." A wire is a wire, and such a wire could carry either power signals, control signals, or composite signals. If a device that does not use both power and control signals is connected to a wire, then the only logical thing to do is to supply that component with the appropriate signal – either a power signal or a control signal. If the device is later replaced with a device that uses both power and control signals in a composite format, then composite signals can be sent to that device through the "already installed" wire. The wire is "already installed" regardless of the device or signals used, so it cannot be maintained that providing composite signals over that pre-installed wire, when the original device attached to it does not use composite signals, provides any advantage.

Furthermore, composite signals are uniquely formatted to control a particular device. One would not remove a headlight and replace that headlight with a heart rate monitor, for example, and expect the heart rate monitor to work. As a minimum, the main CPU would have to be replaced or reprogrammed to provide composite signals with the proper command structure to operate the heart rate monitor. Such replacement or reprogramming is simply is not feasible with bicycle operating systems. If a system does not have a desired functionality, then the entire system is replaced.

The real issue is whether it makes sense to apply composite signals to a device that does not use composite signals, as recited in claim 28, to allow the possibility that the device may be removed in the future and replaced by a device that is exactly suited to the command structure of the existing composite signals. It is submitted that it makes no sense to construct a system with no current benefit and with a substantial of risk of causing malfunctions in the current device, all with the hope that the

system may be modified in the future so that the problems so created will be resolved by substituting the proper device for the mismatched device.

A rejection based on Section 103 must rest on a factual basis, with the facts being interpreted without hindsight reconstruction of the invention from the prior art. To that end, an examiner may not resort to speculation, unfounded assumptions or hindsight reconstruction to supply deficiencies in the factual basis. Ex parte Haymond, 41 USPQ2d 1217 (BdPatApp&Int 1996). The alleged motivations to modify the prior art as set forth in the office action are based on improper speculative hypothetical assumptions, not facts.

The office action further states at page 3, first paragraph, that it would be obvious to use Schwaller's power stabilizing circuit to destroy the control signals to components that do not use such control signals. It is submitted that there is no reason or motivation to intentionally design problematic systems for the satisfaction of including the solution to the problems so created at the same time. There is simply no reason to provide composite signals to a component, such as a headlight, that does not use such signals.

The "pre-installed wire" reasoning provided to support of the rejection of claim 28 is further undermined by the last line in the second paragraph of page 5. As alleged therein, once composite signals are used throughout the Spencer, et al system, then any controlled component that receives the composite signal *must* have a CPU to use the control signal component. That may be true, but such a requirement also multiples the cost and complexity of the system. More specifically, not only do the now-required CPUs increase the hardware costs of the system, but there is the added cost and complexity of programming all of the added CPUs.

It makes no sense to incur the added cost and complexity of multiple CPUs (and their associated programming), and to force a non-controlled component to operate with a composite signal (which requires the cost and complexity of additional circuitry to destroy the control component of the composite signal), just to have a pre-installed wire available for some remote possibility that the non-controlled component may be replaced in the future by a component that requires yet another CPU with its associated programming (not to mention the replacement or

reprogramming of the main processor that will be required to allow the main processor to properly communicate with the new CPU).

Claim 39

Page 3, second paragraph, of the office action states that Spencer, et al teaches a speed indicating signal sent to the gear shift driving component. More specifically, the speed indicating signal is the control signal that controls the gear changer to change gears. It is submitted that such an interpretation is inconsistent with the claim language.

Claim 28, incorporated into claim 39, recites a programmed power/control circuit that receives power from a power supply and *outputs* a composite signal having a power signal component and a control signal component. The office action (at page 4) interpreted the recited power/control circuit to read on Spencer, et al's controller (21).

Spencer, et al teaches signals output from wheel speed sensor (23) and cadence sensor (24). Those signals could be interpreted broadly to be speed indicating signals, but they are *input* to controller (21). The signals from wheel speed sensor (23) and cadence sensor are not output from controller (21). Furthermore, as required by claim 28, wheel speed sensor (23) and cadence sensor (24) are not programmed circuits, and the signals are not composite signals.

The only signals output from Spencer, et al's controller (21) are the signals output to shift motor (29) and the signals output to display (31). Display (31) is not a gear shift controller, so that leaves only shift motor (29). The signals sent to Spencer, et al's shift motor (29) are shown in Fig. 13A. The signals comprise analog signals MOTOR0 and MOTOR1 that are communicated to the inverting input terminals of op amps U8 and U9. The output signals from op amps U8 and U9 provide a differential motor drive signal to motor H1 to determine the direction of rotation of motor H1. In other words, the signals simply provide the power to rotate motor H1 in the desired direction. The signals output to Spencer, et al's shift motor do not indicate speed. One signal is provided for all upshift operations, and another signal is provided for all downshift operations. No information about speed can be derived from those signals.

There is no apparent reason to make a control signal component of a *composite* signal (from claim 28) to comprise a speed indicating signal as recited in claim 39.

Rejection under 35 U.S.C. §103(a) over Spencer, et al, Schwaller and admitted prior art in view of Gohda.

Claims 33 and 47

It is respectfully submitted that claims 33 and 47 derive patentability from their combination with their respective parent claims.

Rejection under 35 U.S.C. §103(a) over Spencer, et al, Schwaller and admitted prior art in view of Tomita.

Claim 40

Page 6 of the office states that it would be obvious to one of ordinary skill in the art at the time of the invention to implement the waveform shaping circuit recited in claim 40 into the modified Spencer, et al invention since Spencer, et al is silent as to how the speed indicating signal is derived and Tomita teaches a method known in the art that would allow for accurate control of the gear shifting driving component via his speedometer and waveform shaping circuit. As further justification for this rejection, page 3 of the office action states that, since Spencer, et al teaches basic ideas (i.e., speed indicating signals and a display) but doesn't explicitly teach the details of these ideas, one of ordinary skill in the art would be motivated to search for an explicit teaching regarding such broad ideas.

Tomita discloses the use of a waveform-shaping circuit to generate speed indicating signals that may be used to display the bicycle speed on a display. A display is not a gear shift driving component, and displays are not used to control gear shift driving components. Thus, it cannot be said that the basic idea of displaying speed on a display motivates one to control a gear shift driving component via the display as alleged in the office action.

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Rejection under 35 U.S.C. §103(a) over Spencer, et al, Schwaller and admitted prior art in view of Turner.

Claim 41

The office action states that Turner discloses an LCD component (186) to display various data, and a second electrical component being the backlight of the LCD display. Turner does not disclose a backlight. As noted previously, not all LCD displays have backlights. Furthermore, as noted previously, it makes no sense to apply a composite signal to a component that is not controlled by the composite signal. That is especially true for a backlight.

Respectfully submitted,

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VIII. CLAIMS APPENDIX

CLAIM 28. A bicycle electrical control apparatus comprising:

a programmed power/control circuit that receives power from a power supply and outputs a composite signal having a power signal component and a control signal component, wherein the control signal component contains information such that the composite signal can be decoded to extract the information contained in the control signal component;

a first electrical bicycle component that receives the composite signal and is controlled by the information contained in the control signal component of the composite signal;

a second electrical bicycle component that receives the composite signal but is not controlled by the control signal component of the composite signal; and

a power stabilizing circuit that receives the composite signal, stabilizes power provided from the composite signal, and provides stabilized power to the second electrical bicycle component.

CLAIM 29. The apparatus according to claim 28 wherein the power/control circuit comprises a CPU.

CLAIM 30. The apparatus according to claim 28 wherein the control signal has a pulse component.

CLAIM 31. The apparatus according to claim 30 wherein the control signal has an ON component and an OFF component.

CLAIM 32. The apparatus according to claim 28 wherein the power stabilizing circuit comprises a capacitor.

CLAIM 33. The apparatus according to claim 32 wherein the power stabilizing circuit further comprises a diode coupled to prevent reverse current from the second electrical bicycle component to the power/control circuit.

CLAIM 34. The apparatus according to claim 28 wherein the power/control circuit is structured to derive the power signal component from an alternating current source.

CLAIM 35. The apparatus according to claim 34 wherein the power/control circuit is structured to derive the power signal component from a dynamo hub mounted to one of a front wheel or a rear wheel of the bicycle.

CLAIM 36. The apparatus according to claim 28 wherein the power/control circuit is structured to derive the power signal component from a direct current source.

CLAIM 37. The apparatus according to claim 36 wherein the power/control circuit is structured to derive the power signal component from a battery.

CLAIM 38. The apparatus according to claim 28 wherein the power stabilizing circuit stabilizes the power provided from the power signal component to the second electrical bicycle component but not to the first electrical bicycle component.

CLAIM 39. The apparatus according to claim 28 wherein the control signal component comprises a speed indicating signal.

CLAIM 40. The apparatus according to claim 39 wherein the power/control circuit includes a waveform shaping circuit that derives the speed indicating signal from the output of an alternating current generator.

CLAIM 41. The apparatus according to claim 28 wherein the first electrical bicycle component comprises a liquid crystal display component structured to display various data, and wherein the second electrical bicycle component comprises a backlight that illuminates the liquid crystal display component.

CLAIM 42. The apparatus according to claim 28 wherein the first electrical bicycle component comprises a gear shift driving component that drives a gear shift mechanism having a plurality of gear ratios.

CLAIM 43. The apparatus according to claim 42 wherein the second electrical bicycle component comprises a light.

CLAIM 44. The apparatus according to claim 28 wherein the power stabilizing circuit stabilizes a voltage provided to the second electrical bicycle component.

CLAIM 45. The apparatus according to claim 44 wherein the power stabilizing circuit comprises a power storage device coupled in parallel with the second electrical bicycle component.

CLAIM 46. The apparatus according to claim 45 wherein the power storage device comprises a capacitor.

CLAIM 47. The apparatus according to claim 46 wherein the power stabilizing circuit further comprises a diode coupled to prevent reverse current from the capacitor to the power/control circuit.

CLAIM 48. The apparatus according to claim 28 wherein the first electrical bicycle component comprises a CPU that receives the composite signal and is controlled by the control signal component of the composite signal.

IX. EVIDENCE APPENDIX

1) U.S. Patent No. 6,047,230 issued to Spencer, et al and entered into the record by the examiner in the office action dated June 20, 2006.

2) U.S. Patent No. 5,247,430 issued to Schwaller and entered into the record by the examiner in the office action dated October 5, 2005.

3) U.S. Patent No. 4,609,982 issued to Gohda and entered into the record by the examiner in the office action dated October 5, 2005.

4) Japanese Patent Publication No. 07-229,909 naming Tomita and entered into the record by the examiner in the office action dated December 27, 2006.

5) U.S. Patent Application Publication No. 2002/0014366 naming Turner and entered into the record by the examiner in the office action dated October 5, 2005.

US006047230A

United States Patent [19]

Spencer et al.

[11] **Patent Number:** 6,047,230

[45] **Date of Patent:** Apr. 4, 2000

[54] **AUTOMATIC BICYCLE TRANSMISSION**

[76] Inventors: **Marc D. Spencer**, 121 Brunswick St., Rochester, N.Y. 14607; **Gregory J. Lukins**, 123 Wintergreen Way, Rochester, N.Y. 14618-4631; **Ezra R. Gold**, 180 Elm Ct. #1805, Sunnyvale, Calif. 94086; **Frank Duver**, 38 Bayview Dr., Apt. D, Northport, N.Y. 11768; **Bruce Arden**, 101 N. Main St., Apt. 906, Ann Arbor, Mich. 48104

[21] Appl. No.: **08/807,354**

[22] Filed: **Feb. 27, 1997**

[51] **Int. Cl.**[7] **F16H 9/00**

[52] **U.S. Cl.** **701/57**; 701/51; 701/59; 474/70; 474/78

[58] **Field of Search** 701/51, 55, 56, 701/57, 59; 474/70, 80, 81, 110

[56] **References Cited**

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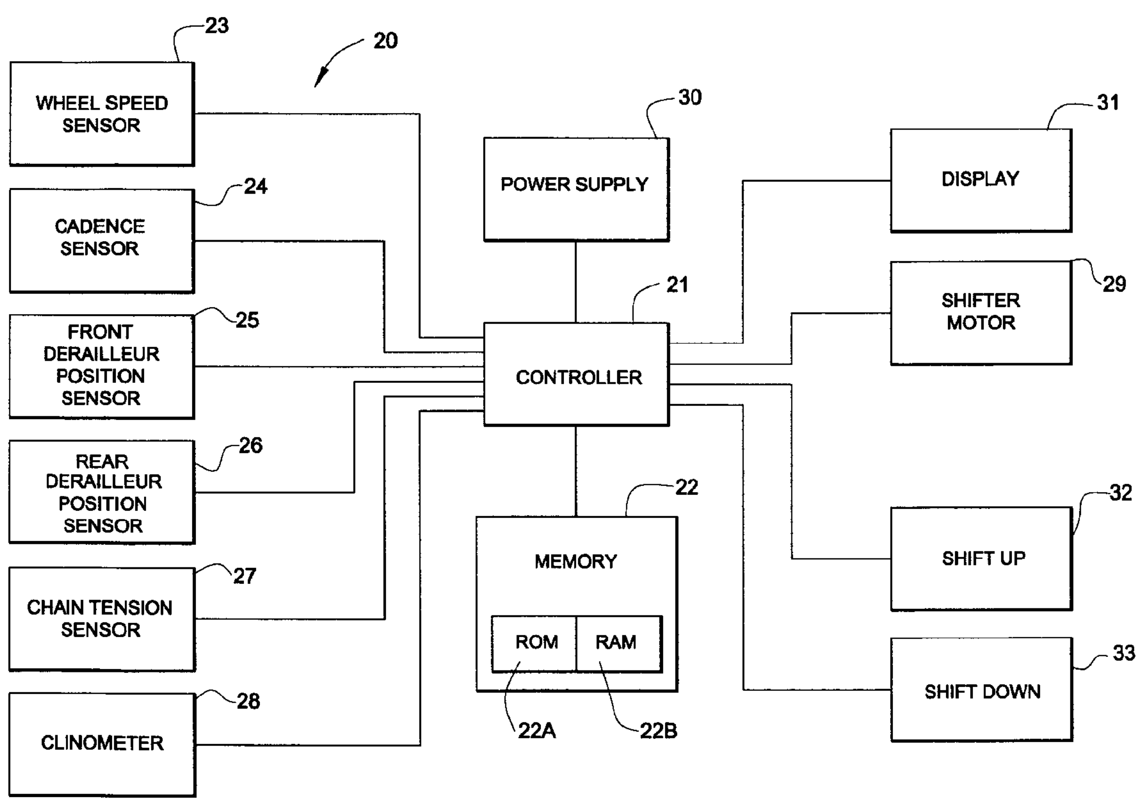
Primary Examiner—Tan Nguyen

Attorney, Agent, or Firm—Banner & Witcoff, Ltd.

[57] **ABSTRACT**

A gear shifting system for a human-powered chain- or belt-driven vehicle includes a wheel speed sensor, a cadence sensor, a gear changer position sensor, a tension sensor, a clinometer, a controller and a gear changer actuator. The wheel speed sensor senses a speed of a wheel, while the cadence sensor senses a drive rate that a torque drive member drives a torque-transmitting member. The gear changer position sensor senses a position of a gear changer that positions the torque-transmitting member with respect to a plurality of gears. The tension sensor senses a tension of the torque-transmitting member that is transmitting a torque applied to the torque-transmitting drive member to a gear. The clinometer senses an inclination of the vehicle. The controller generates a control signal based on the sensed wheel speed, the sensed torque-member drive rate, the sensed torque-transmitting member tension, the sensed vehicle inclination and the sensed gear changer position. The gear changer actuator is coupled to the gear changer and moves the gear changer in response to the control signal by positioning the torque-transmitting member with respect to the plurality of gears.

27 Claims, 24 Drawing Sheets



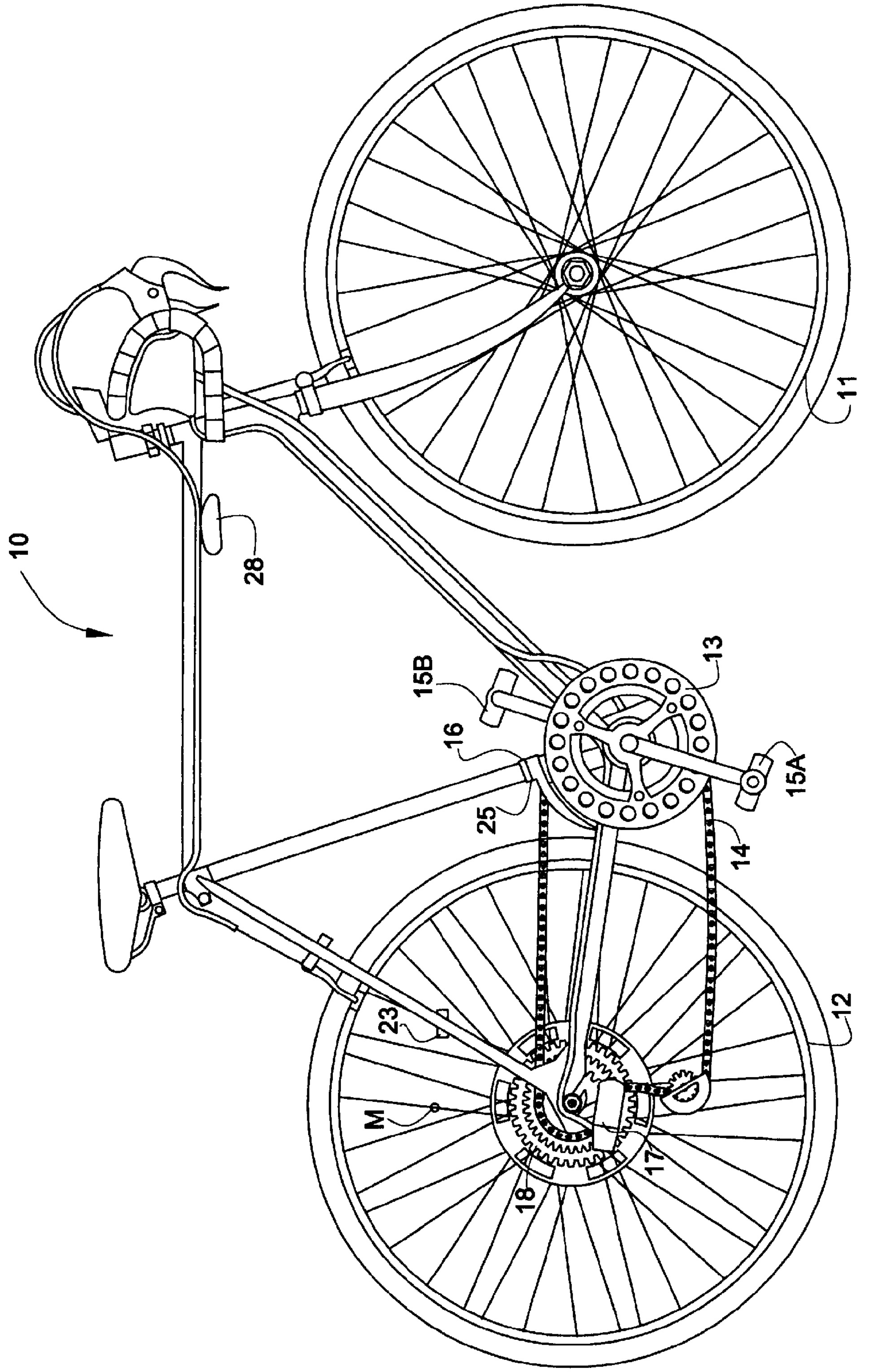
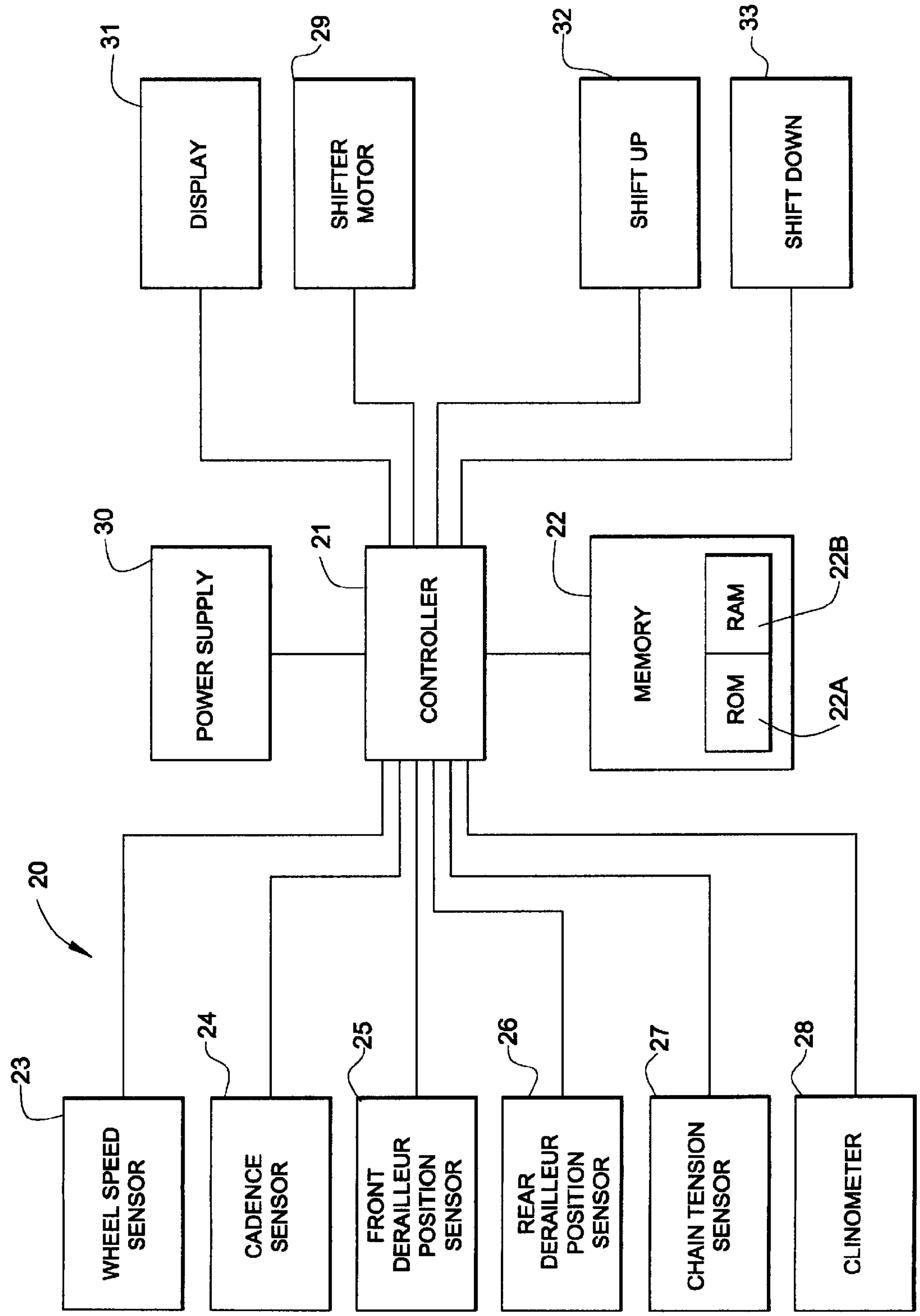


FIG. 1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CLINOMETER
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FIG. 2

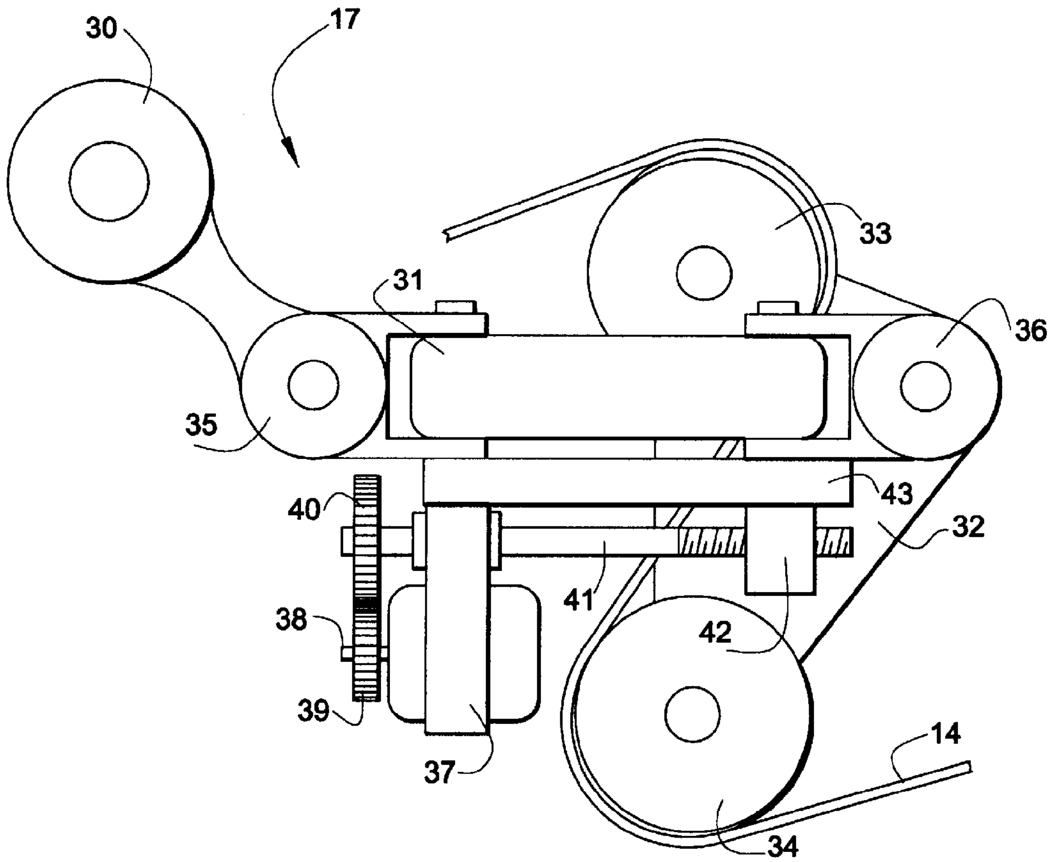
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FIG. 3

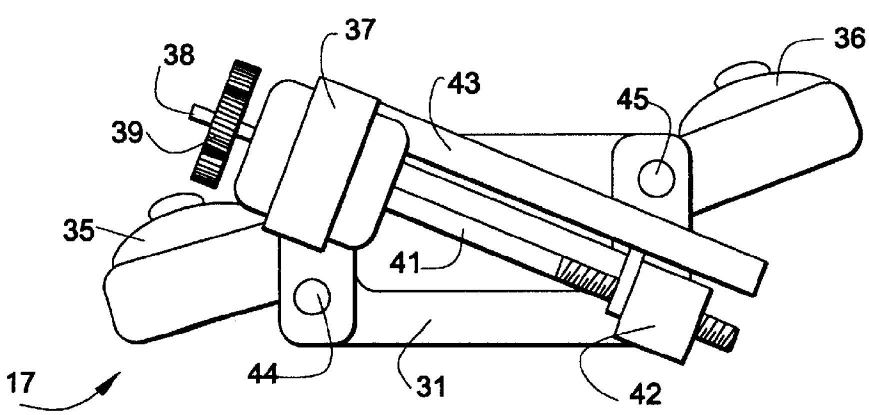
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FIG. 4

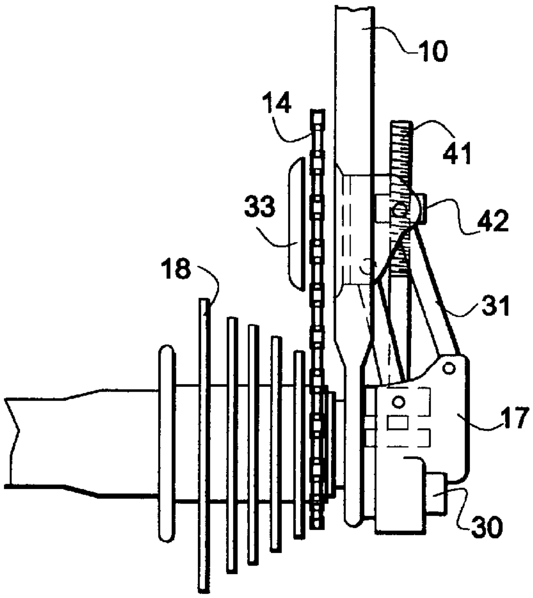

FIG. 5A

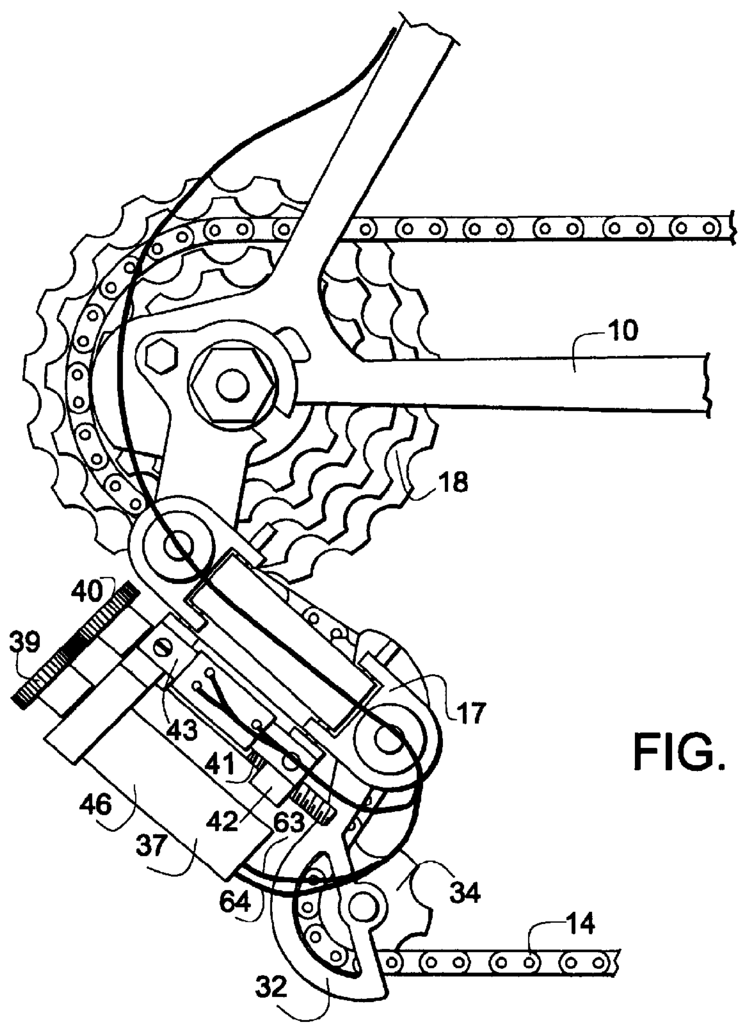

FIG. 5B

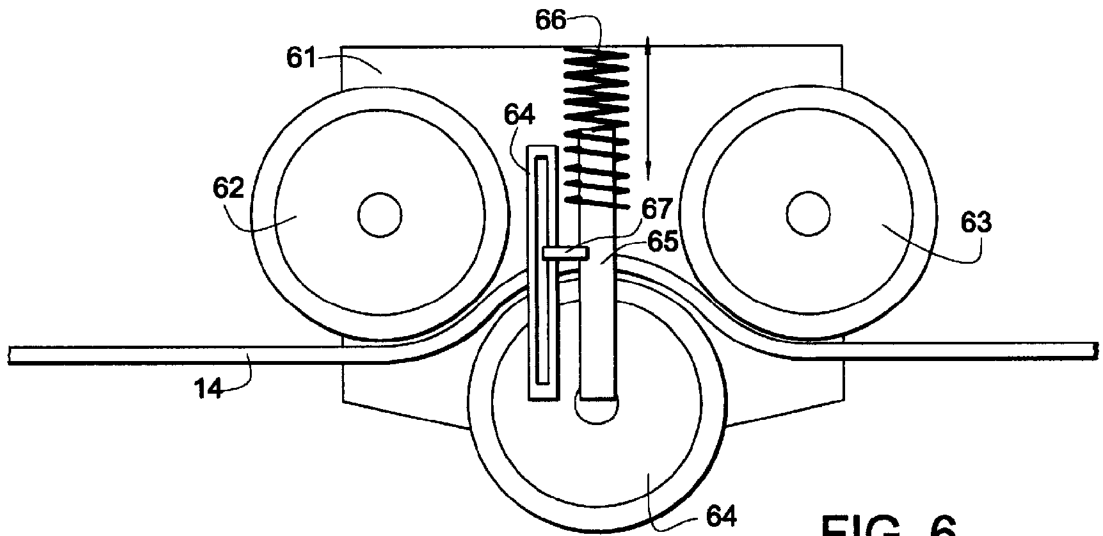

FIG. 6

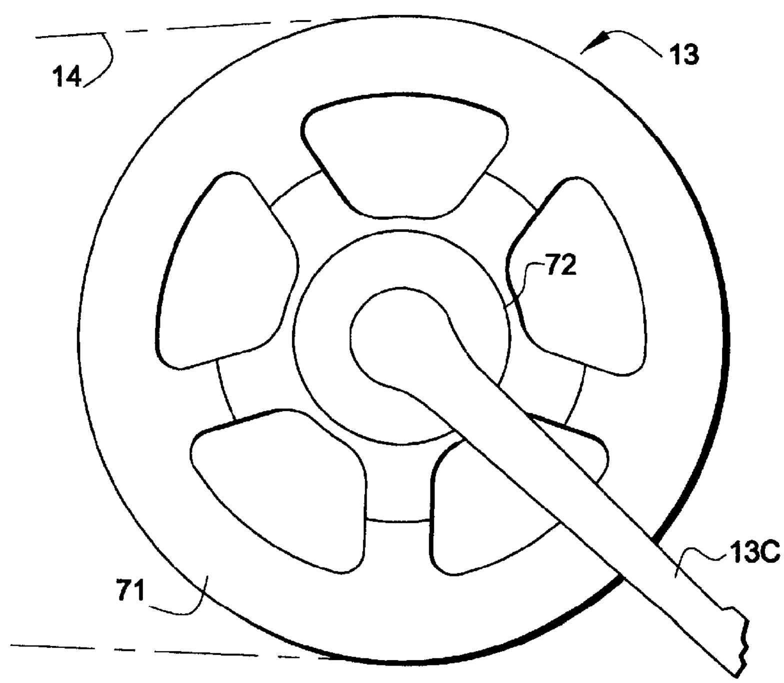

FIG. 7

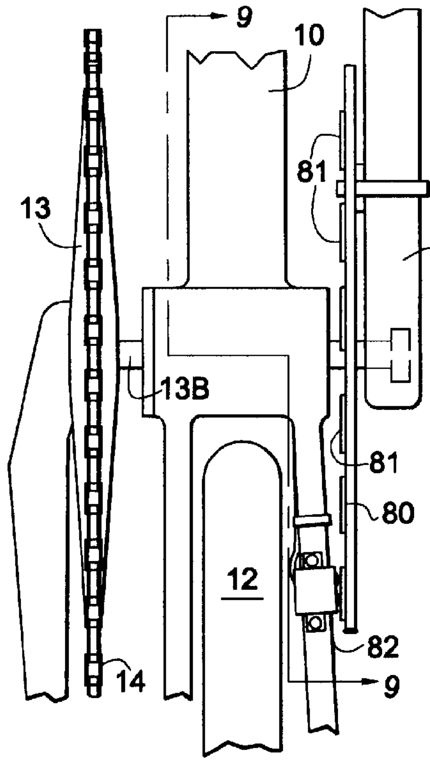
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FIG. 8

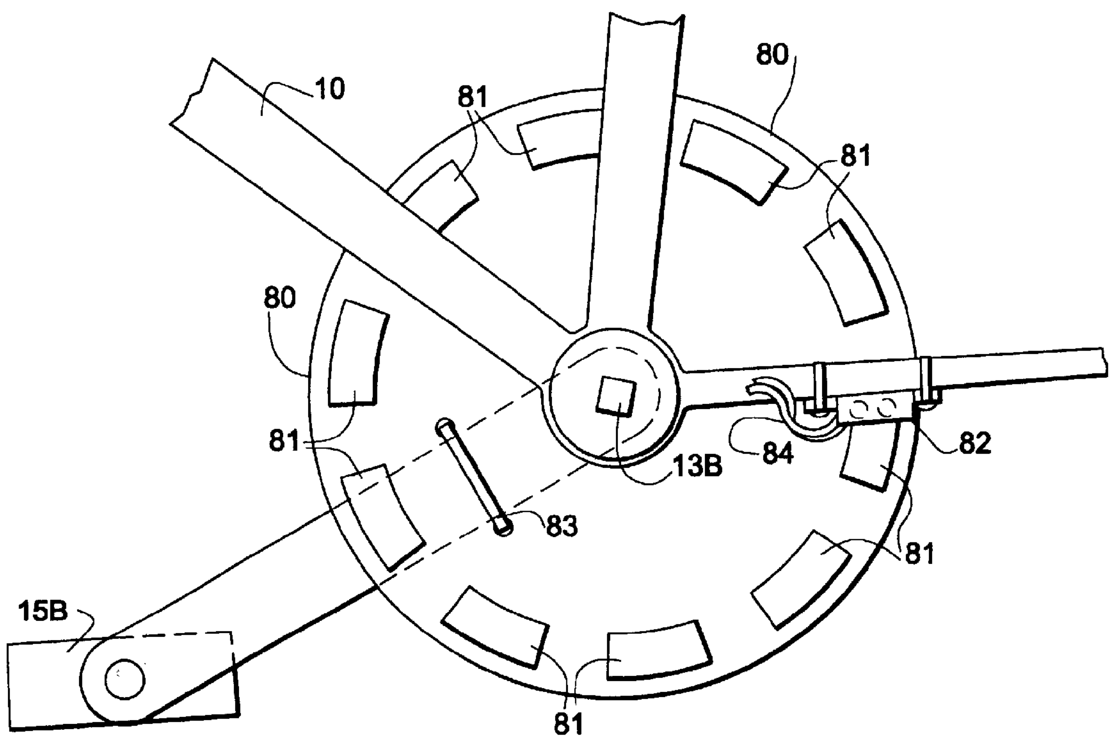
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FIG. 9

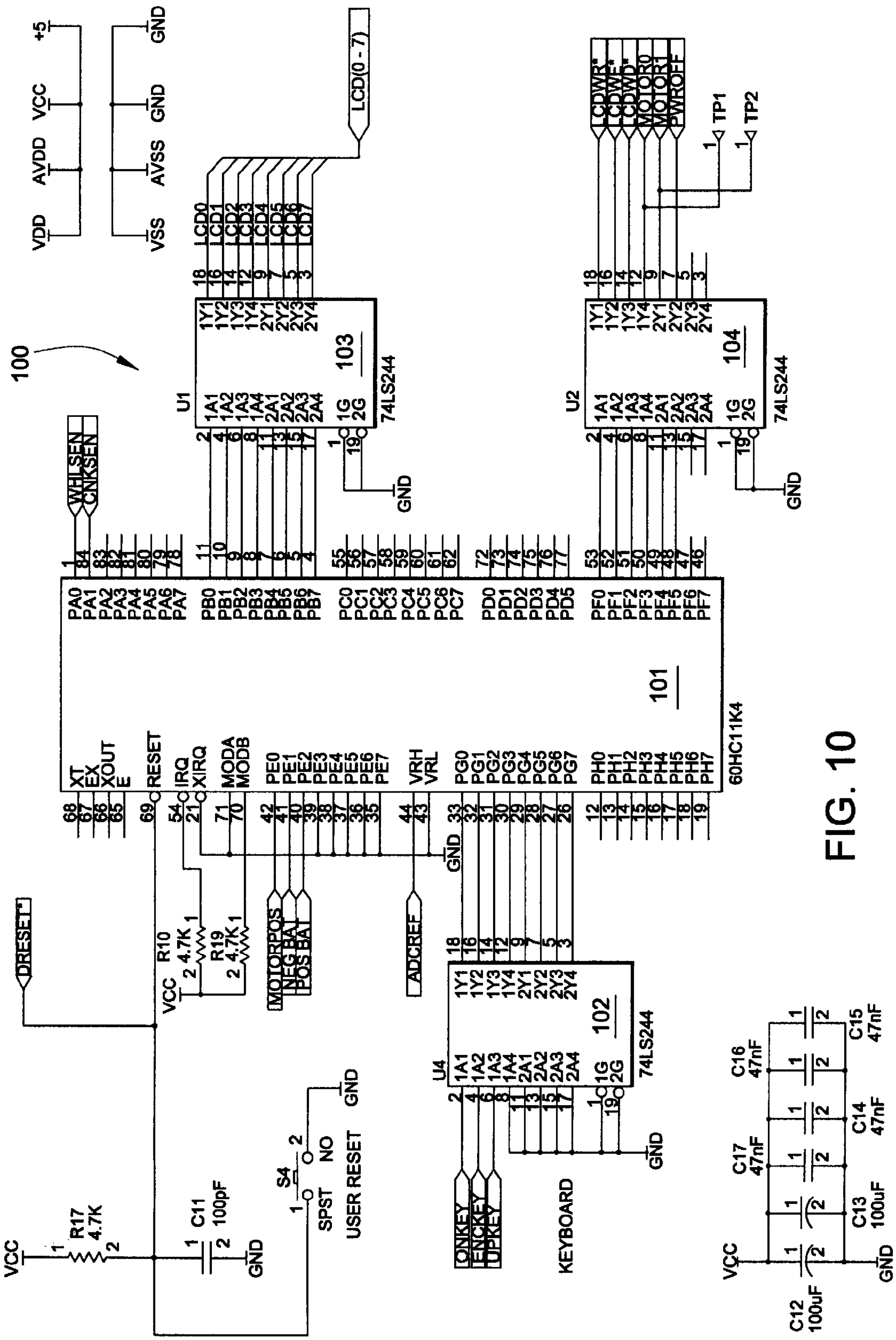
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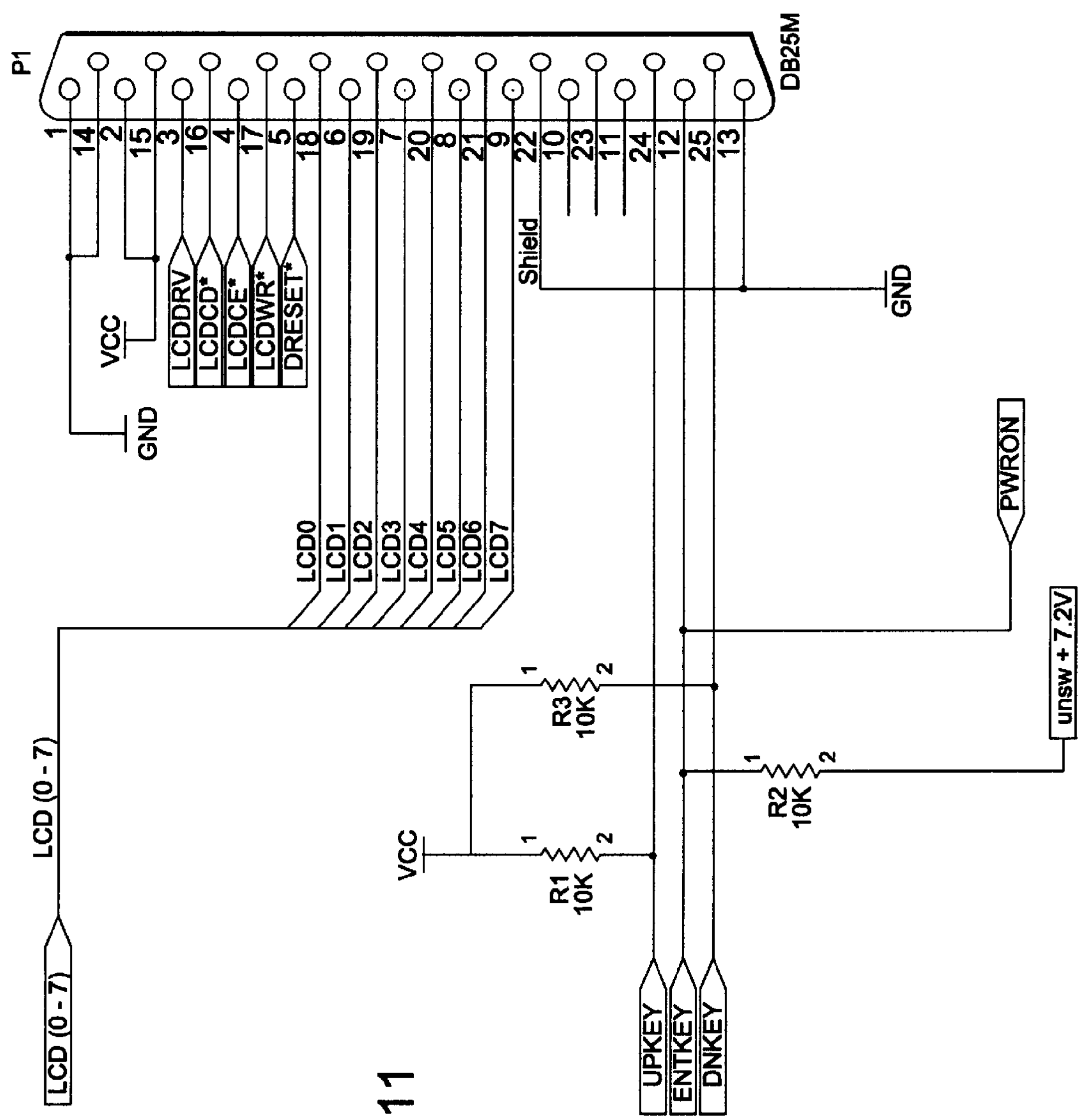
FIG. 10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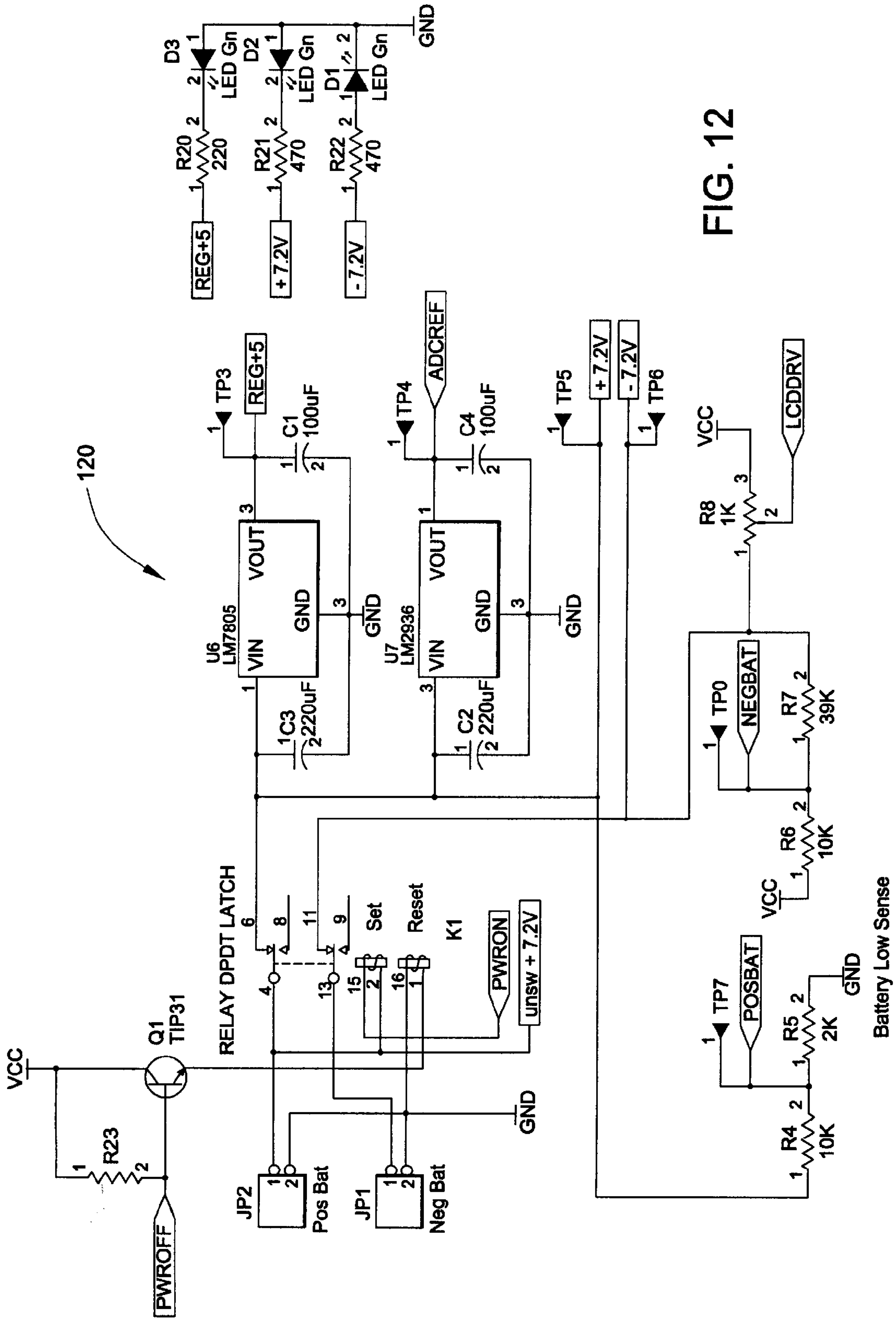
9
22
10
23
11
24
12
25
13
VCC
GND
LCDDRV
LCDCD*
LCDCE*
LCDWR*
DRESET*
Shield
GND
PWRON
LCD0
LCD1
LCD2
LCD3
LCD4
LCD5
LCD6
LCD7
unsw + 7.2V
R3
10K
R2
10K
R1
10K
VCC
LCD (0 - 7)
LCD (0 - 7)
UPKEY
ENTKEY
DNKEY

FIG. 11



120
D3
LED Gn
D2
LED Gn
D1
LED Gn
GND
R20
220
R21
470
R22
470
REG+5
+ 7.2V
- 7.2V
TP3
REG+5
C1
100uF
U6
LM7805
VIN
VOUT
GND
C3
220uF
TP4
ADCREF
C4
100uF
U7
LM2936
VIN
VOUT
GND
C2
220uF
TP5
+ 7.2V
- 7.2V
TP6
VCC
LCDDRV
R8
1K
TP0
NEGBAT
R7
39K
R6
10K
VCC
RELAY DPDT LATCH
Set
Reset
K1
PWRON
unsw + 7.2V
Q1
TIP31
VCC
R23
PWROFF
JP2
Pos Bat
JP1
Neg Bat
GND
TP7
POSBAT
R5
2K
GND
R4
10K
Battery Low Sense

FIG. 12

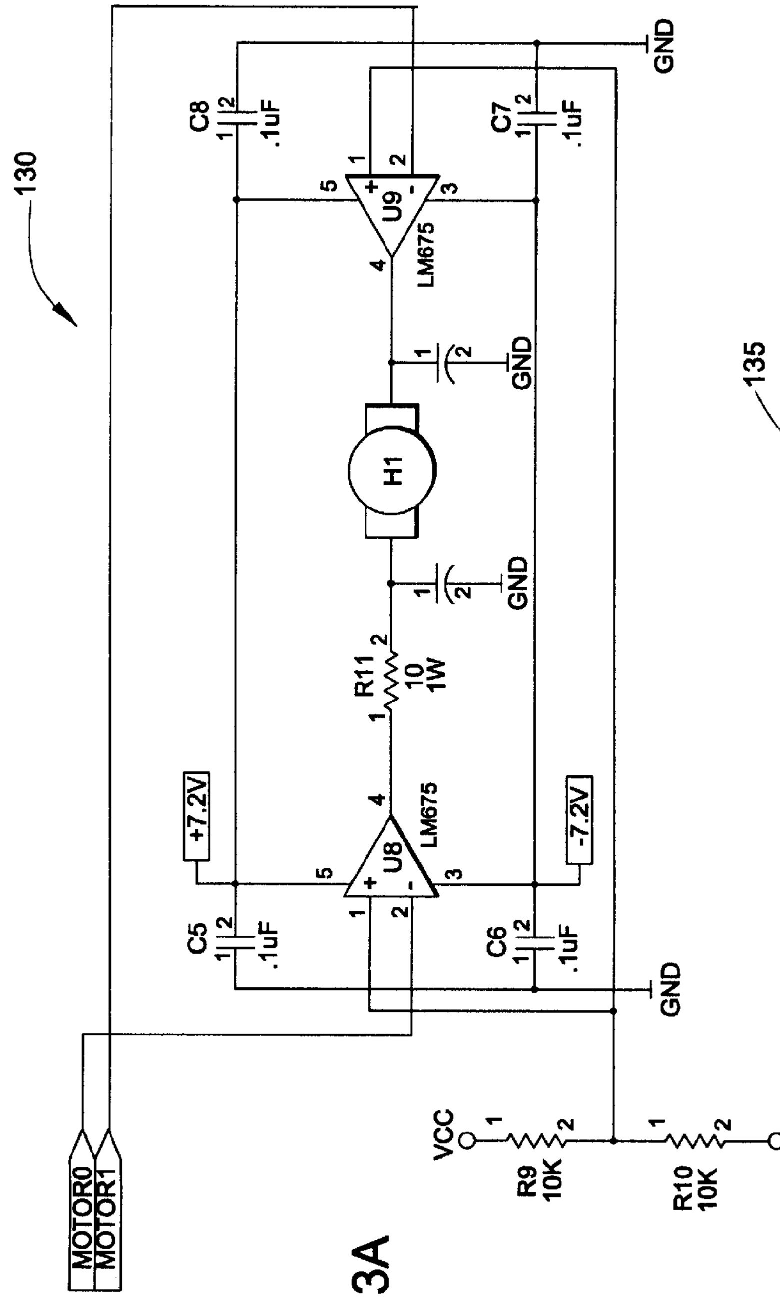


FIG. 13A

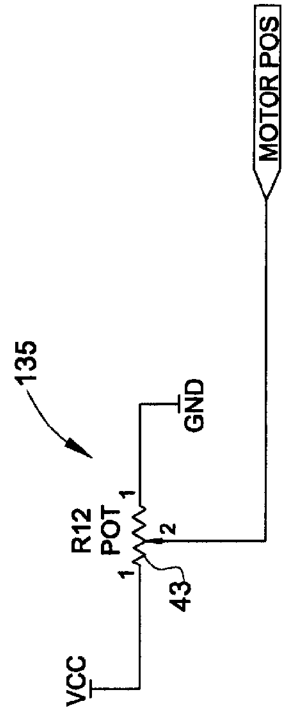
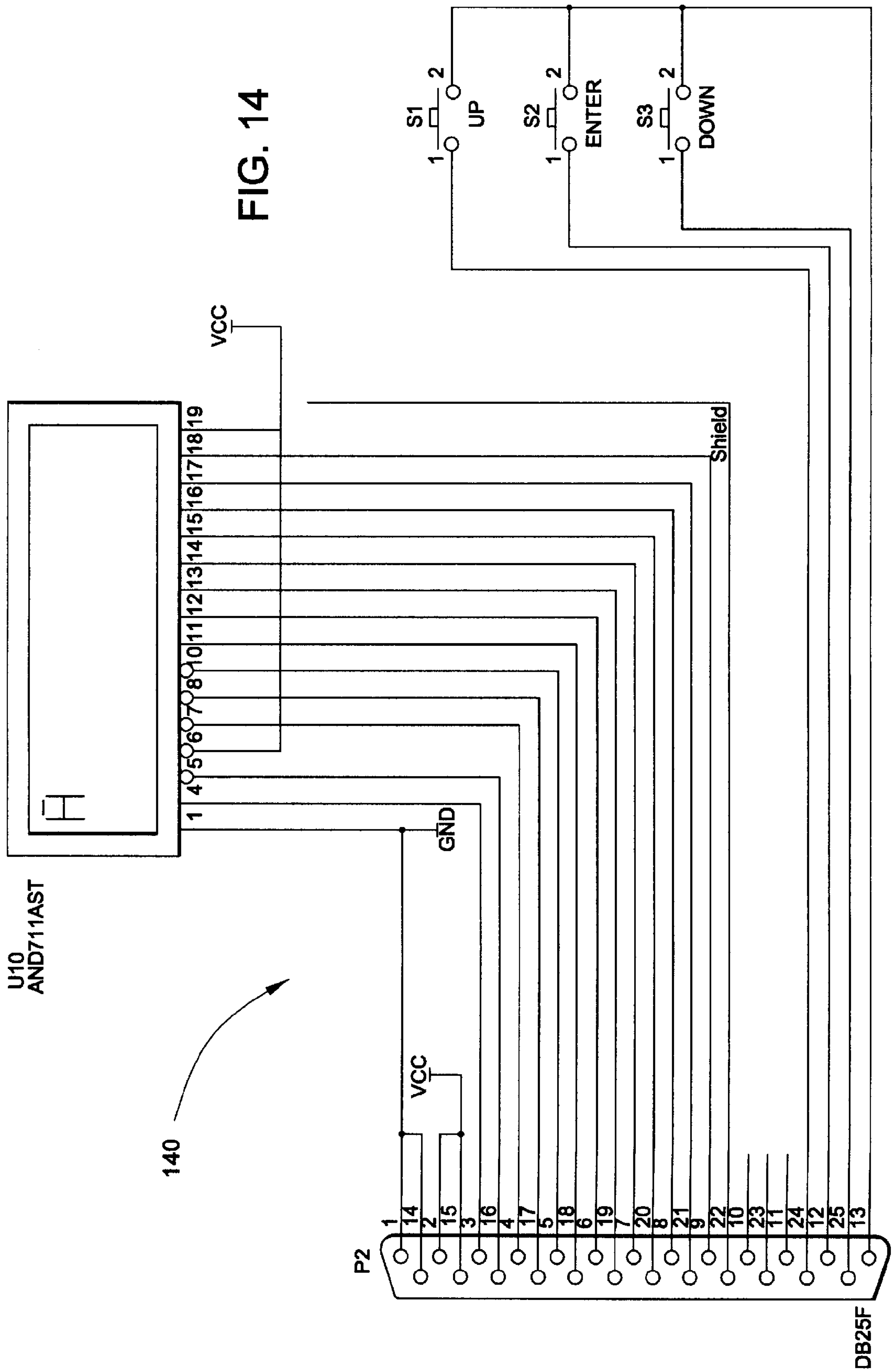


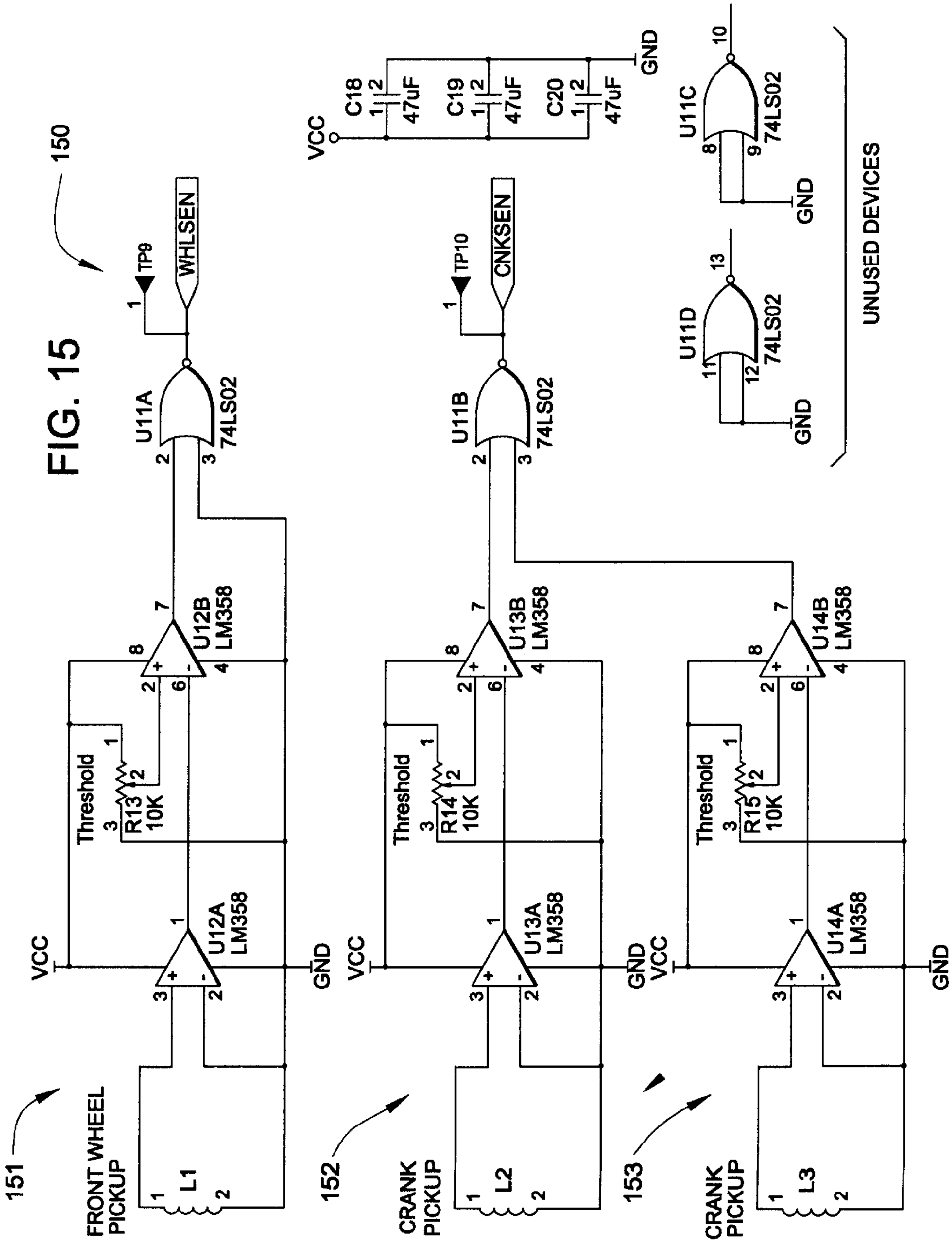
FIG. 13B



140
U10
AND711AST
VCC
GND
Shield
S1
UP
S2
ENTER
S3
DOWN
P2
DB25F

FIG. 14

FIG. 15


150
151
FRONT WHEEL PICKUP
L1
152
CRANK PICKUP
L2
153
CRANK PICKUP
L3
VCC
GND
U12A LM358
U13A LM358
U14A LM358
Threshold
R13 10K
R14 10K
R15 10K
U12B LM358
U13B LM358
U14B LM358
U11A 74LS02
U11B 74LS02
TP9
TP10
WHLSEN
CNKSEN
C18 47uF
C19 47uF
C20 47uF
U11C 74LS02
U11D 74LS02
UNUSED DEVICES

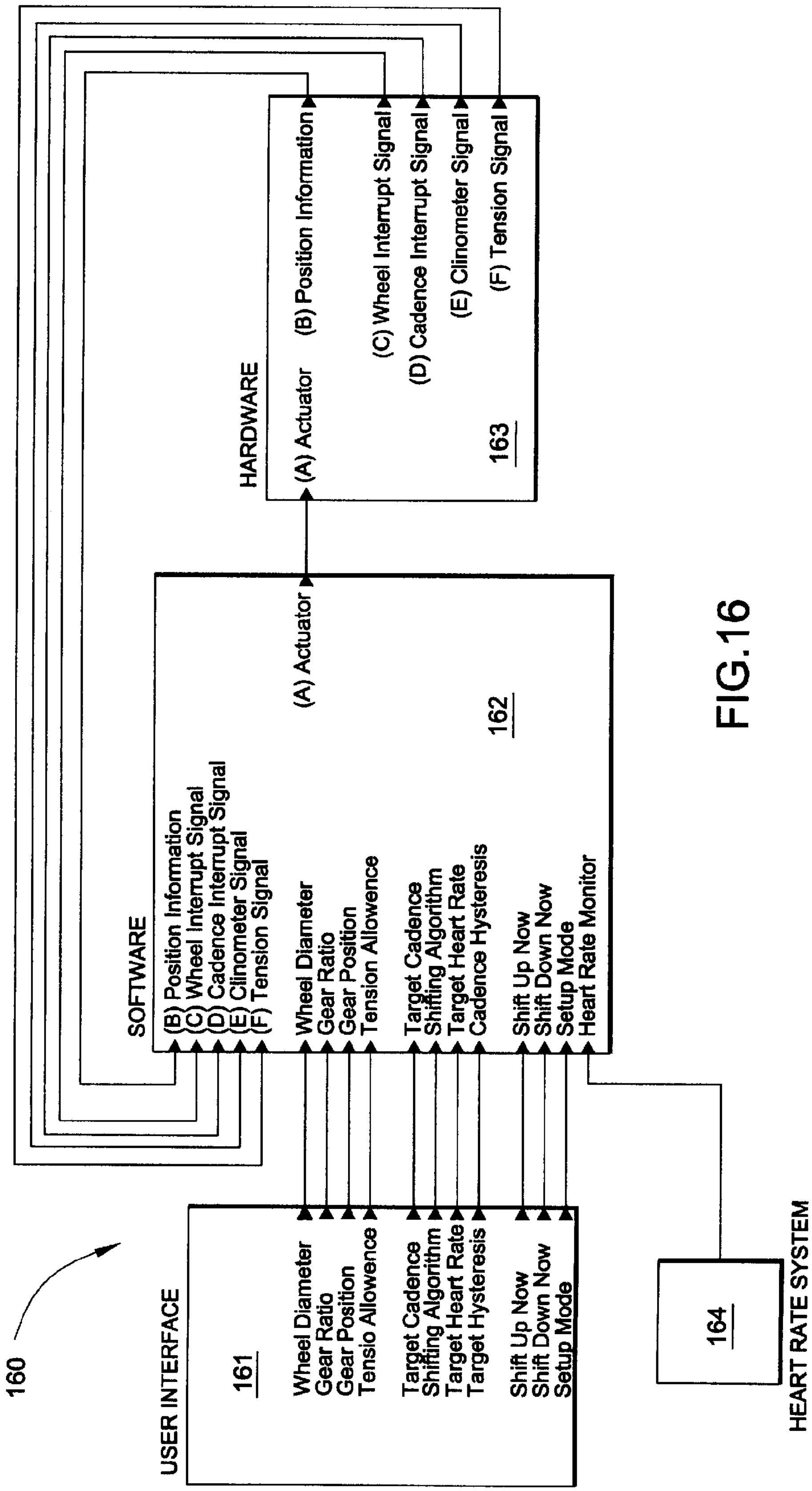

160
USER INTERFACE
161
Wheel Diameter
Gear Ratio
Gear Position
Tensio Allowence
Target Cadence
Shifting Algorithm
Target Heart Rate
Target Hysteresis
Shift Up Now
Shift Down Now
Setup Mode
SOFTWARE
(B) Position Information
(C) Wheel Interrupt Signal
(D) Cadence Interrupt Signal
(E) Clinometer Signal
(F) Tension Signal
Wheel Diameter
Gear Ratio
Gear Position
Tension Allowence
Target Cadence
Shifting Algorithm
Target Heart Rate
Cadence Hysteresis
Shift Up Now
Shift Down Now
Setup Mode
Heart Rate Monitor
(A) Actuator
162
HARDWARE
(A) Actuator
(B) Position Information
(C) Wheel Interrupt Signal
(D) Cadence Interrupt Signal
(E) Clinometer Signal
(F) Tension Signal
163
164
HEART RATE SYSTEM

FIG.16

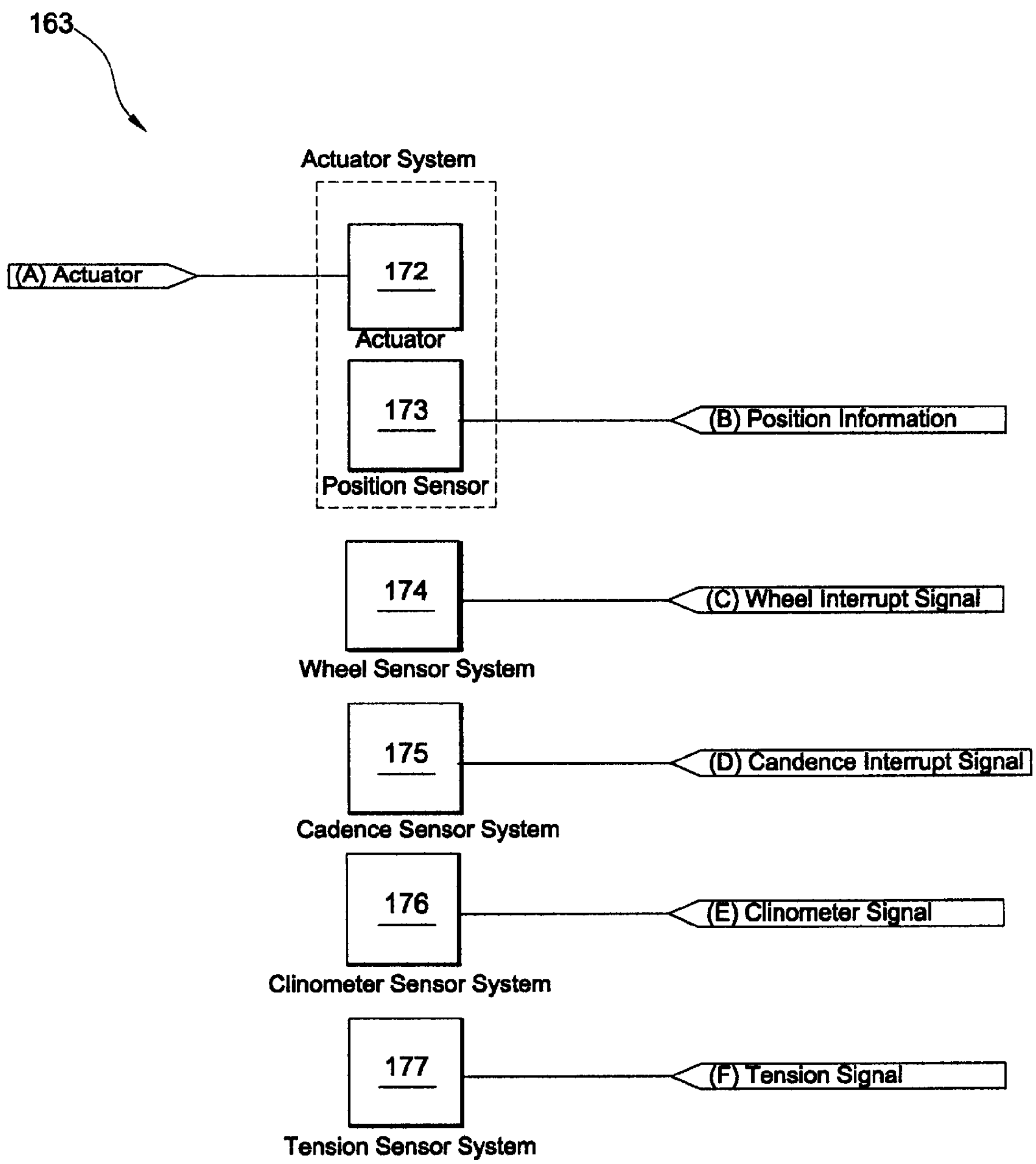
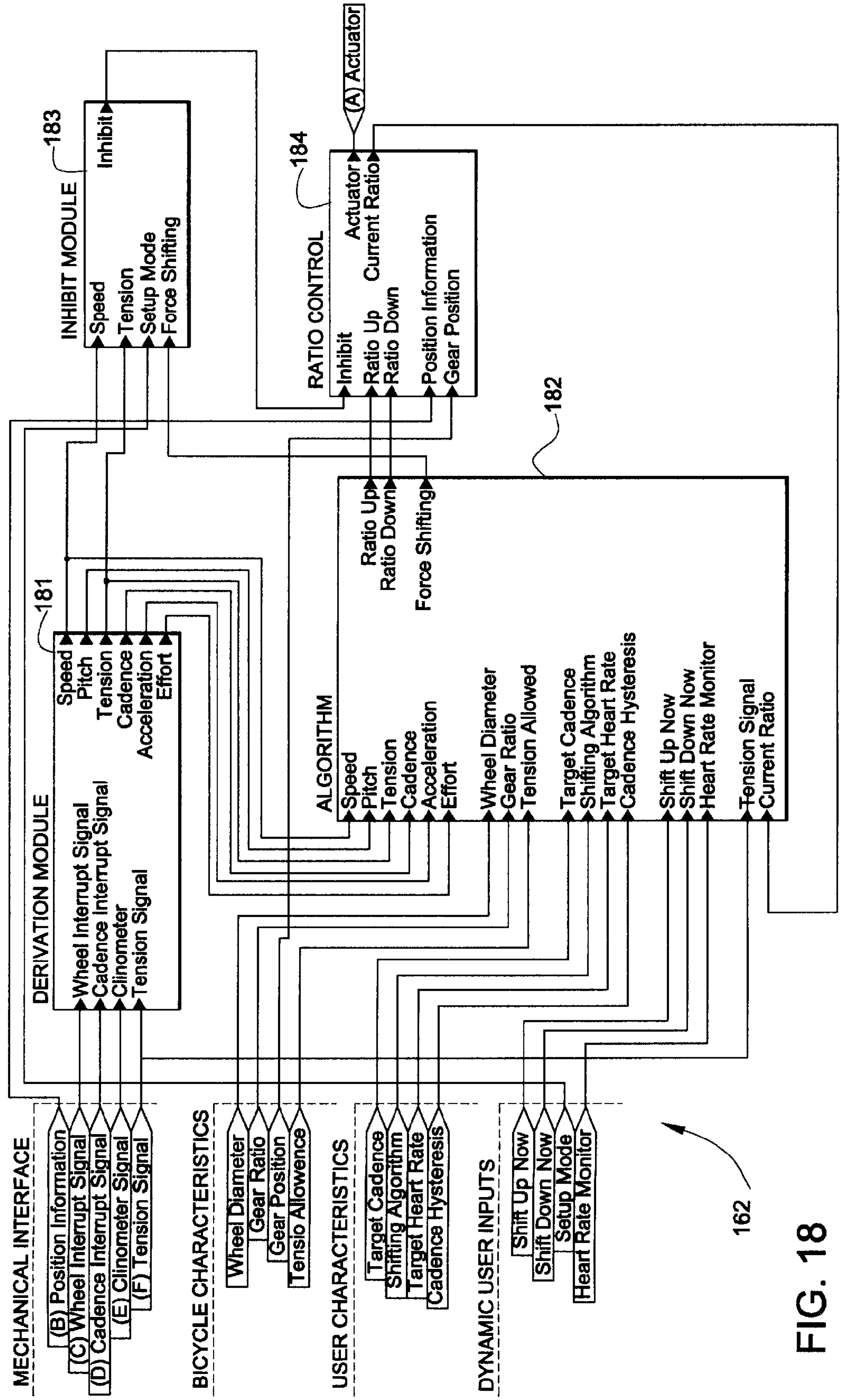

163
Actuator System
(A) Actuator
172
Actuator
173
Position Sensor
(B) Position Information
174
(C) Wheel Interrupt Signal
Wheel Sensor System
175
(D) Candence Interrupt Signal
Cadence Sensor System
176
(E) Clinometer Signal
Clinometer Sensor System
177
(F) Tension Signal
Tension Sensor System

FIG. 17



INHIBIT MODULE
183
Speed
Tension
Setup Mode
Force Shifting
Inhibit
RATIO CONTROL
184
Inhibit
Ratio Up
Ratio Down
Position Information
Gear Position
Actuator
Current Ratio
(A) Actuator
182
ALGORITHM
Ratio Up
Ratio Down
Force Shifting
Speed
Pitch
Tension
Cadence
Acceleration
Effort
Wheel Diameter
Gear Ratio
Tension Allowed
Target Cadence
Shifting Algorithm
Target Heart Rate
Cadence Hysteresis
Shift Up Now
Shift Down Now
Heart Rate Monitor
Tension Signal
Current Ratio
181
DERIVATION MODULE
Wheel Interrupt Signal
Cadence Interrupt Signal
Clinometer
Tension Signal
Speed
Pitch
Tension
Cadence
Acceleration
Effort
MECHANICAL INTERFACE
(B) Position Information
(C) Wheel Interrupt Signal
(D) Cadence Interrupt Signal
(E) Clinometer Signal
(F) Tension Signal
BICYCLE CHARACTERISTICS
Wheel Diameter
Gear Ratio
Gear Position
Tensio Allowence
USER CHARACTERISTICS
Target Cadence
Shifting Algorithm
Target Heart Rate
Cadence Hysteresis
DYNAMIC USER INPUTS
Shift Up Now
Shift Down Now
Setup Mode
Heart Rate Monitor
162

FIG. 18

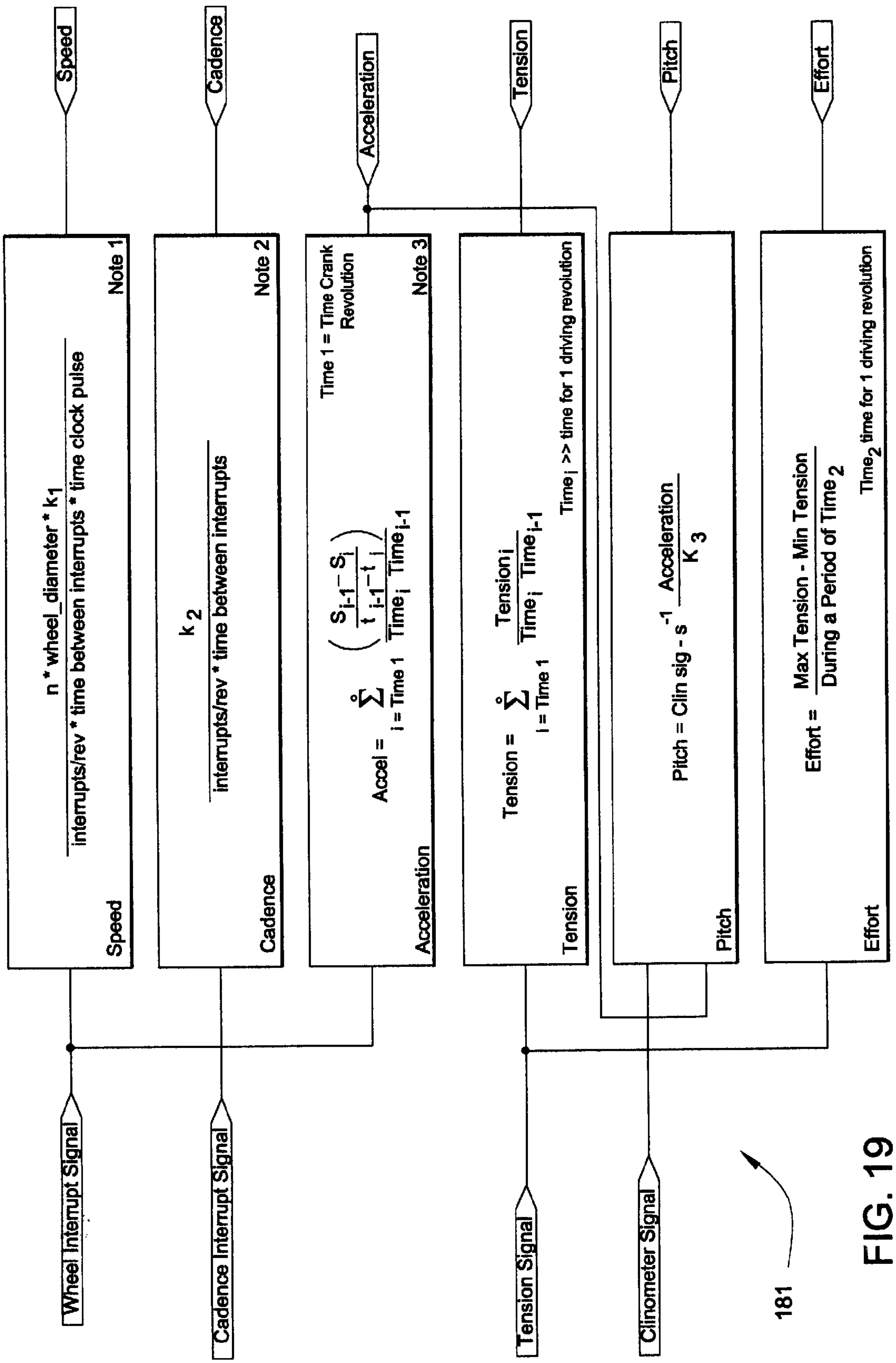

Speed
Cadence
Acceleration
Tension
Pitch
Effort
Note 1
n * wheel_diameter * k1 / interrupts/rev * time between interrupts * time clock pulse
Speed
Note 2
k2 / interrupts/rev * time between interrupts
Cadence
Time 1 = Time Crank Revolution
Note 3
Accel = Σ i = Time 1 (S i-1 − S i / t i-1 − t i) / Time i Time i-1
Acceleration
Tension = Σ i = Time 1 Tension i / Time i Time i-1
Time i >> time for 1 driving revolution
Tension
Pitch = Clin sig - s^-1 Acceleration / K3
Pitch
Effort = Max Tension - Min Tension / During a Period of Time 2
Time2 time for 1 driving revolution
Effort
Wheel Interrupt Signal
Cadence Interrupt Signal
Tension Signal
Clinometer Signal
181

FIG. 19

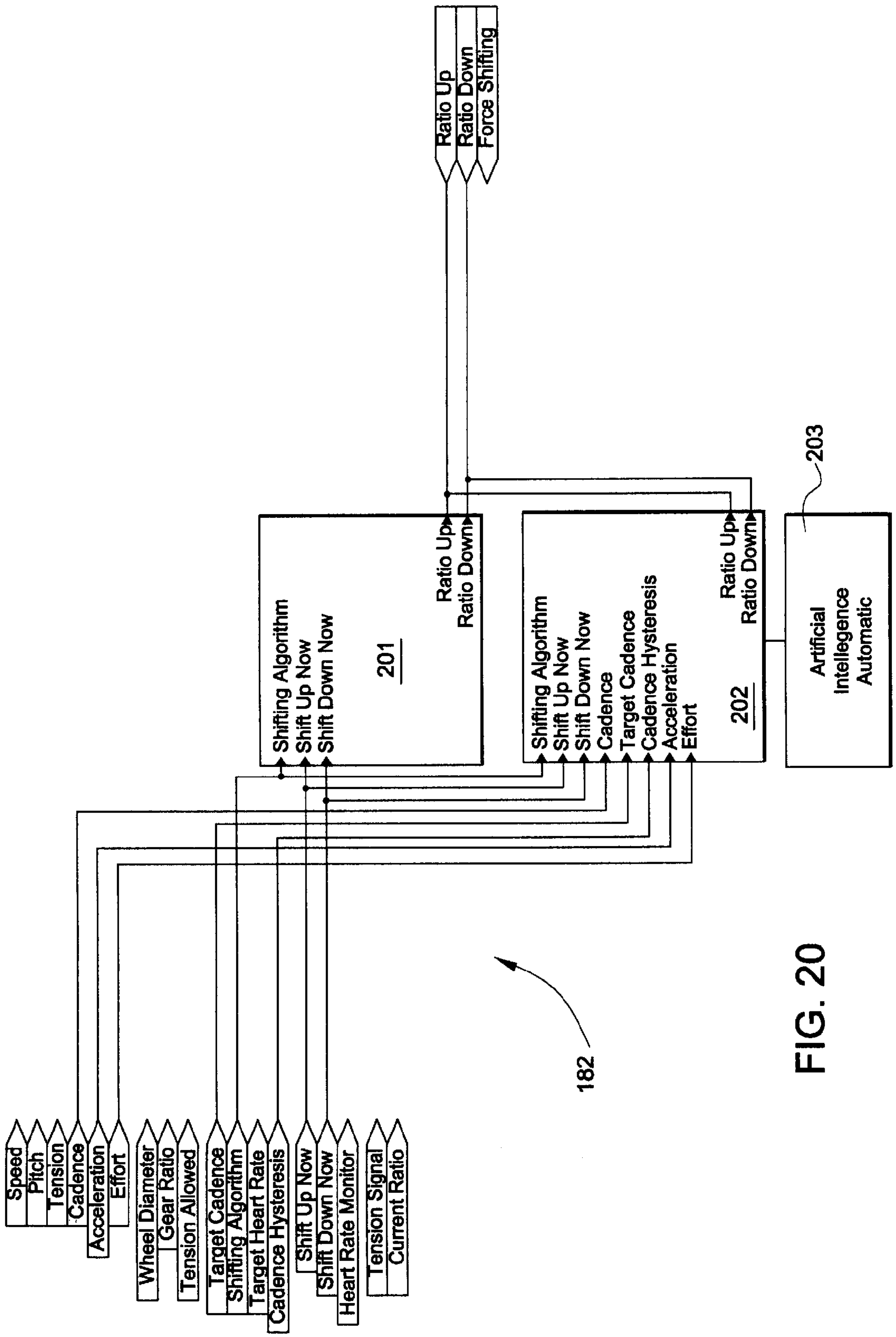

Ratio Up
Ratio Down
Force Shifting
Shifting Algorithm
Shift Up Now
Shift Down Now
201
Ratio Up
Ratio Down
Shifting Algorithm
Shift Up Now
Shift Down Now
Cadence
Target Cadence
Cadence Hysteresis
Acceleration
Effort
202
Ratio Up
Ratio Down
Artificial
Intellegence
Automatic
203
182
Speed
Pitch
Tension
Cadence
Acceleration
Effort
Wheel Diameter
Gear Ratio
Tension Allowed
Target Cadence
Shifting Algorithm
Target Heart Rate
Cadence Hysteresis
Shift Up Now
Shift Down Now
Heart Rate Monitor
Tension Signal
Current Ratio

FIG. 20

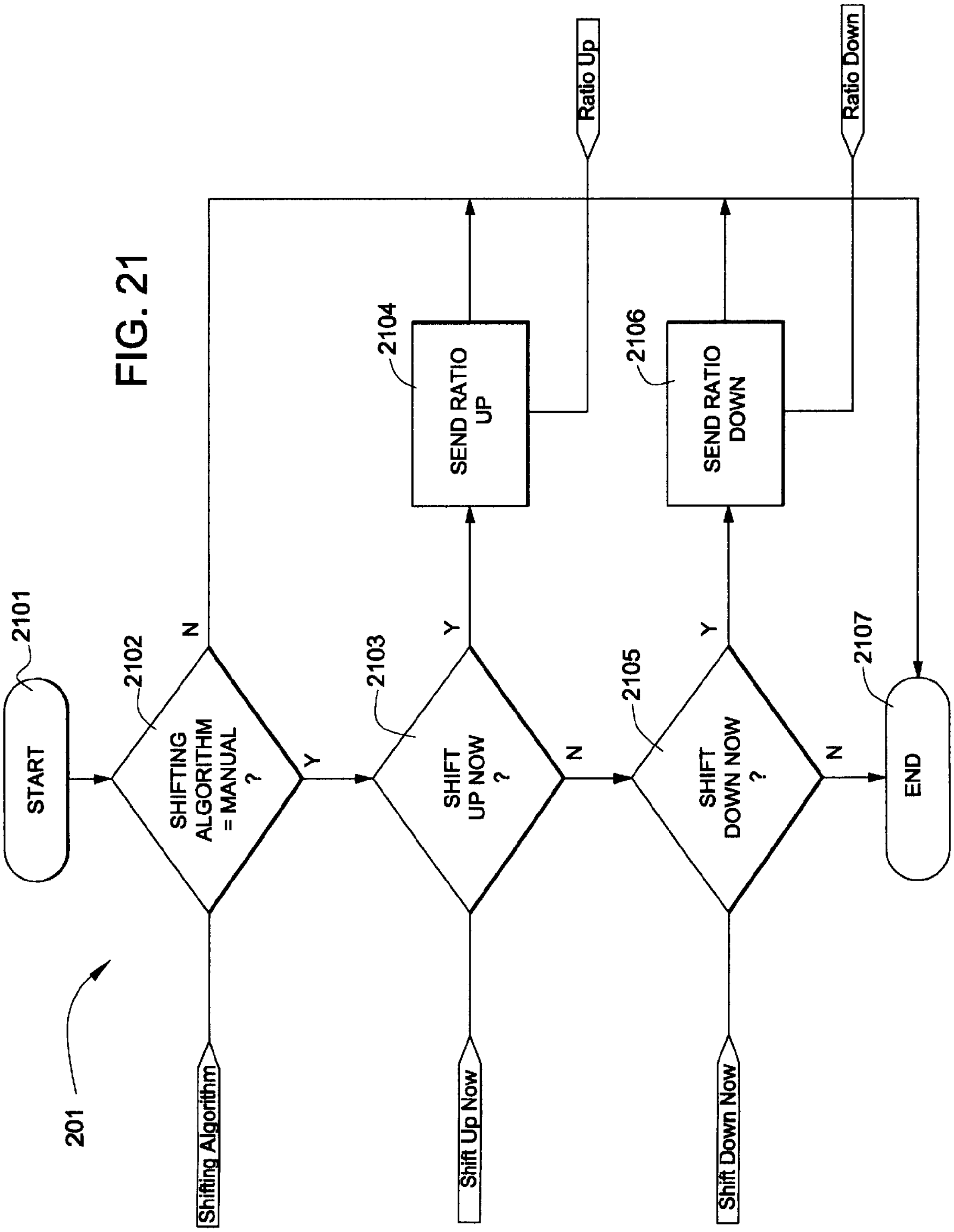
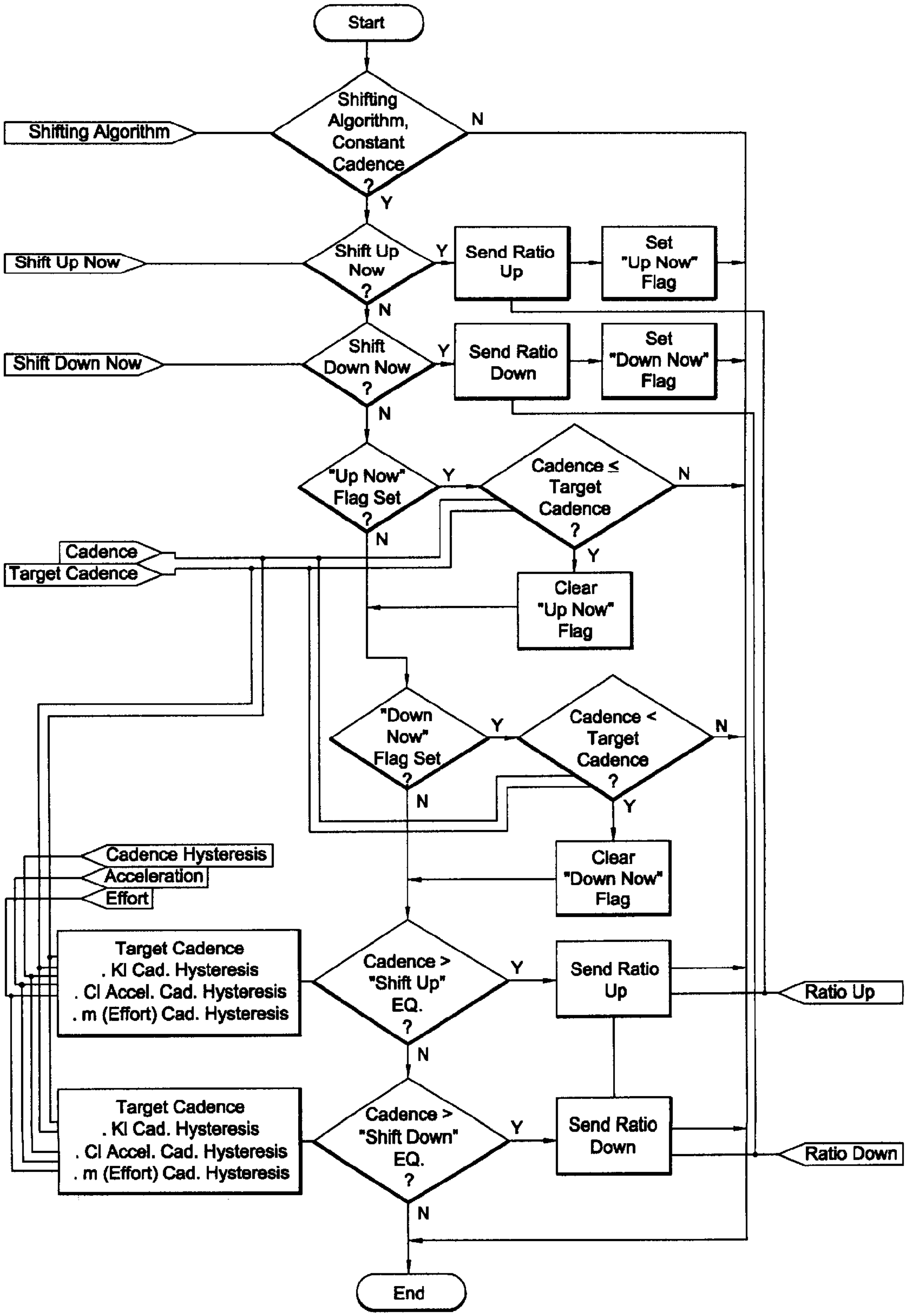

START
SHIFTING ALGORITHM = MANUAL ?
SHIFT UP NOW ?
SHIFT DOWN NOW ?
END
SEND RATIO UP
SEND RATIO DOWN
Shifting Algorithm
Shift Up Now
Shift Down Now
Ratio Up
Ratio Down
Y
N
201
2101
2102
2103
2104
2105
2106
2107

FIG. 21


Start
Shifting Algorithm
Shifting Algorithm, Constant Cadence ?
N
Y
Shift Up Now
Shift Up Now ?
Y
Send Ratio Up
Set "Up Now" Flag
N
Shift Down Now
Shift Down Now ?
Y
Send Ratio Down
Set "Down Now" Flag
N
"Up Now" Flag Set ?
Y
Cadence ≤ Target Cadence ?
N
Y
Cadence
Target Cadence
Clear "Up Now" Flag
"Down Now" Flag Set ?
Y
Cadence < Target Cadence ?
N
Y
Clear "Down Now" Flag
Cadence Hysteresis
Acceleration
Effort
Target Cadence . Kl Cad. Hysteresis . Cl Accel. Cad. Hysteresis . m (Effort) Cad. Hysteresis
Cadence > "Shift Up" EQ. ?
Y
Send Ratio Up
Ratio Up
N
Target Cadence . Kl Cad. Hysteresis . Cl Accel. Cad. Hysteresis . m (Effort) Cad. Hysteresis
Cadence > "Shift Down" EQ. ?
Y
Send Ratio Down
Ratio Down
N
End

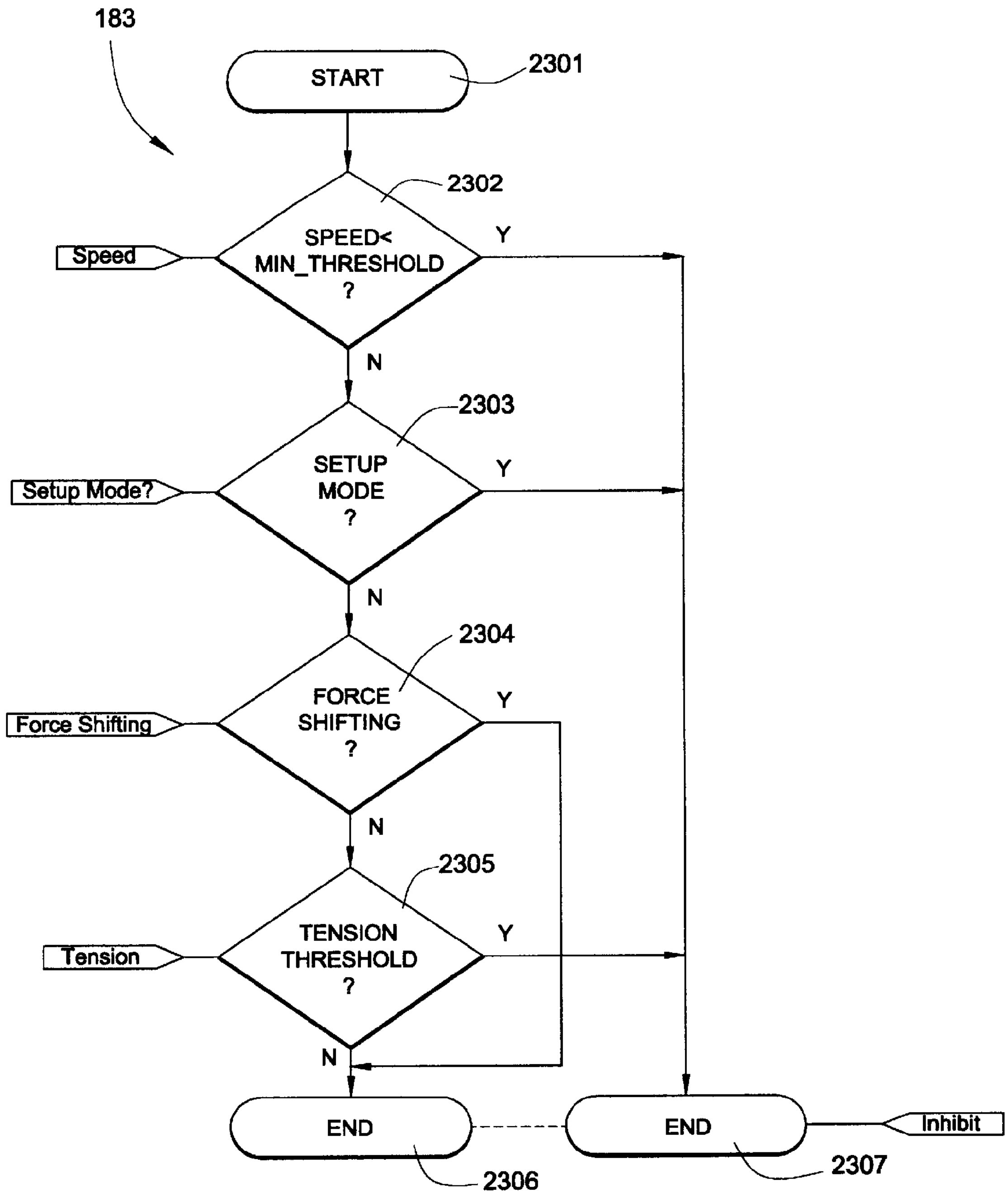

183
START
2301
2302
Speed
SPEED<
MIN_THRESHOLD
?
Y
N
2303
Setup Mode?
SETUP
MODE
?
Y
N
2304
Force Shifting
FORCE
SHIFTING
?
Y
N
2305
Tension
TENSION
THRESHOLD
?
Y
N
END
END
Inhibit
2306
2307

FIG. 23

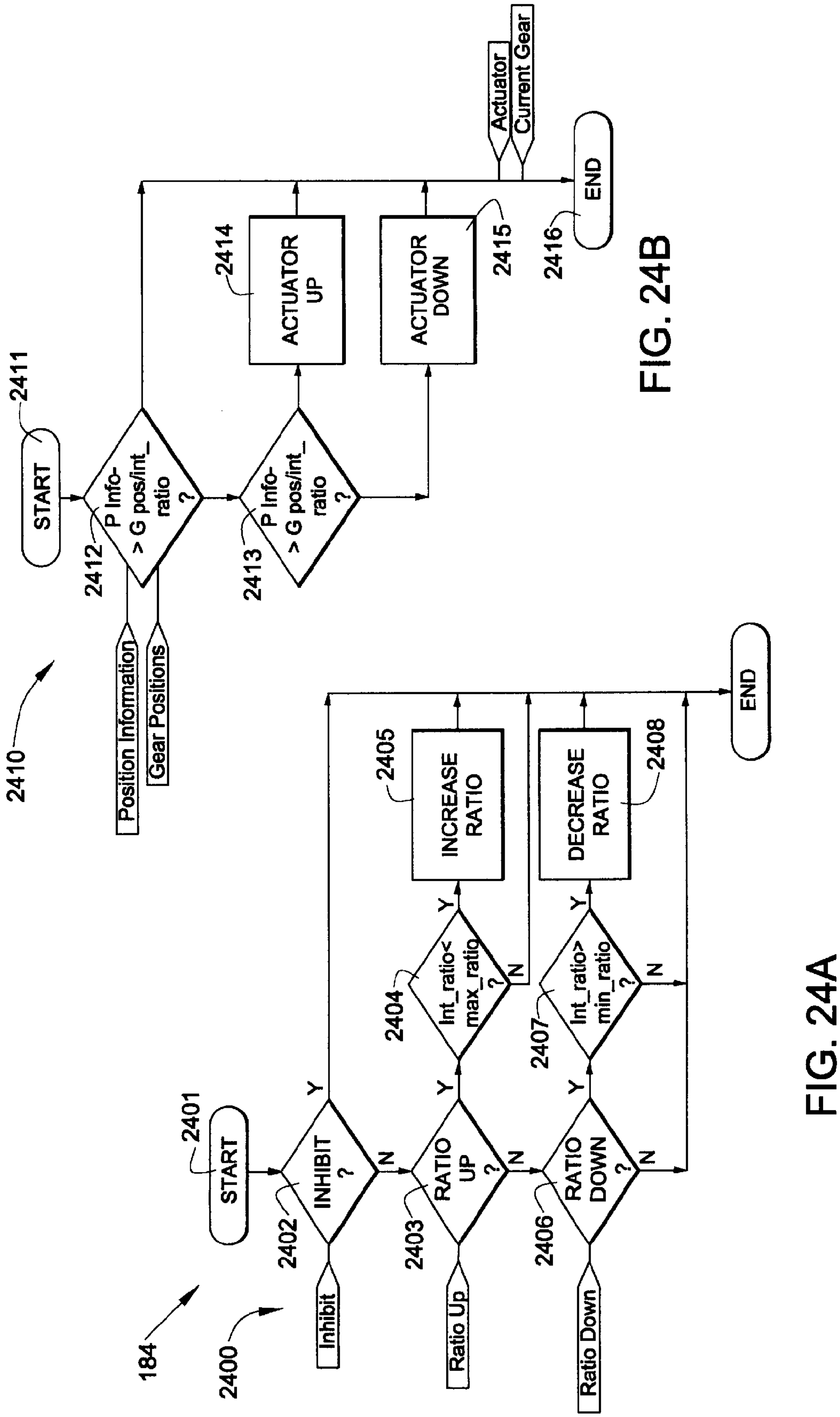


FIG. 24B

FIG. 24A

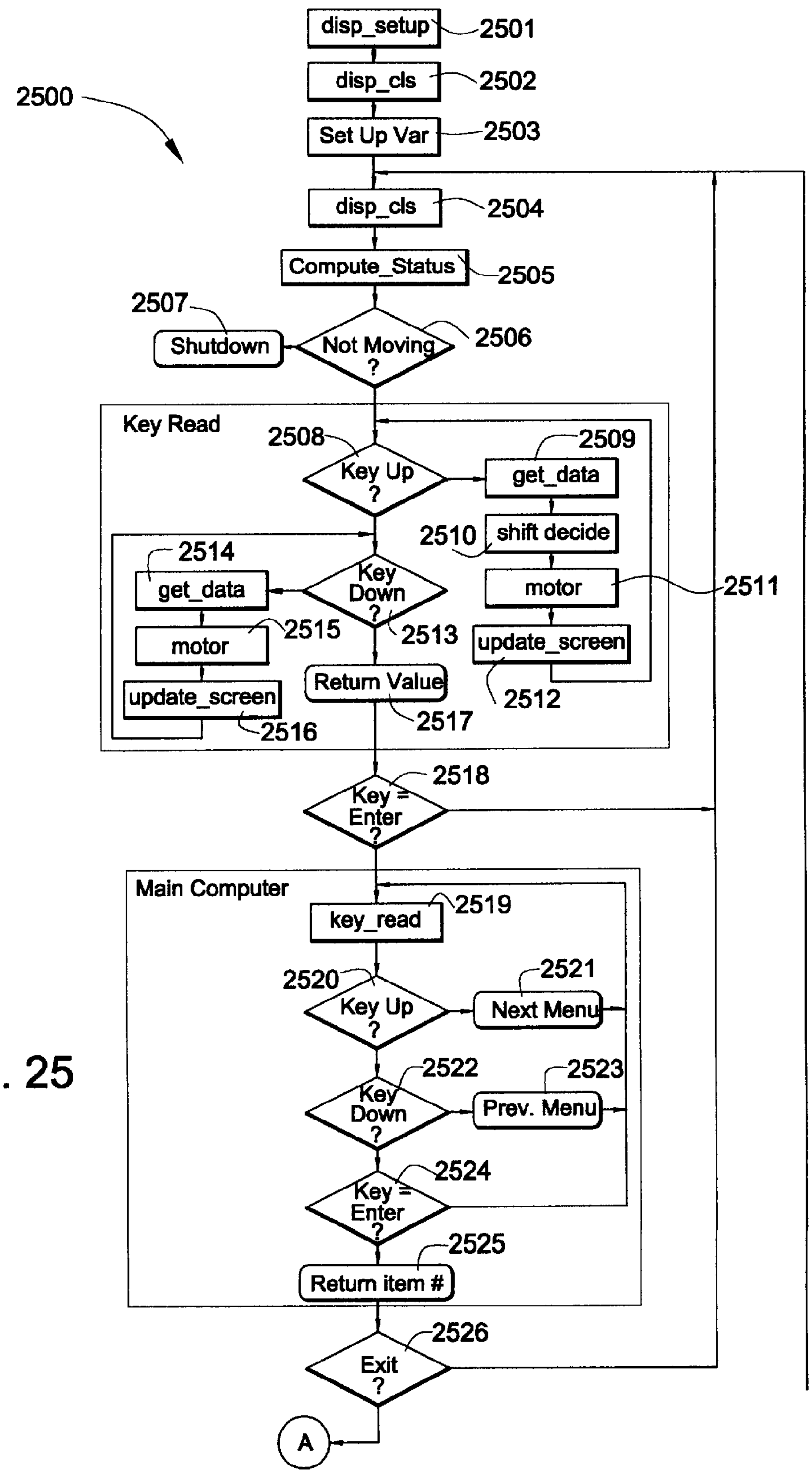

2500
disp_setup
2501
disp_cls
2502
Set Up Var
2503
disp_cls
2504
Compute_Status
2505
2507
Shutdown
Not Moving ?
2506
Key Read
2508
Key Up ?
2509
get_data
2510
shift decide
motor
2511
2514
get_data
Key Down ?
2515
motor
2513
update_screen
Return Value
update_screen
2512
2516
2517
2518
Key = Enter ?
Main Computer
key_read
2519
2520
2521
Key Up ?
Next Menu
2522
2523
Key Down ?
Prev. Menu
2524
Key = Enter ?
2525
Return item #
2526
Exit ?
A

FIG. 25

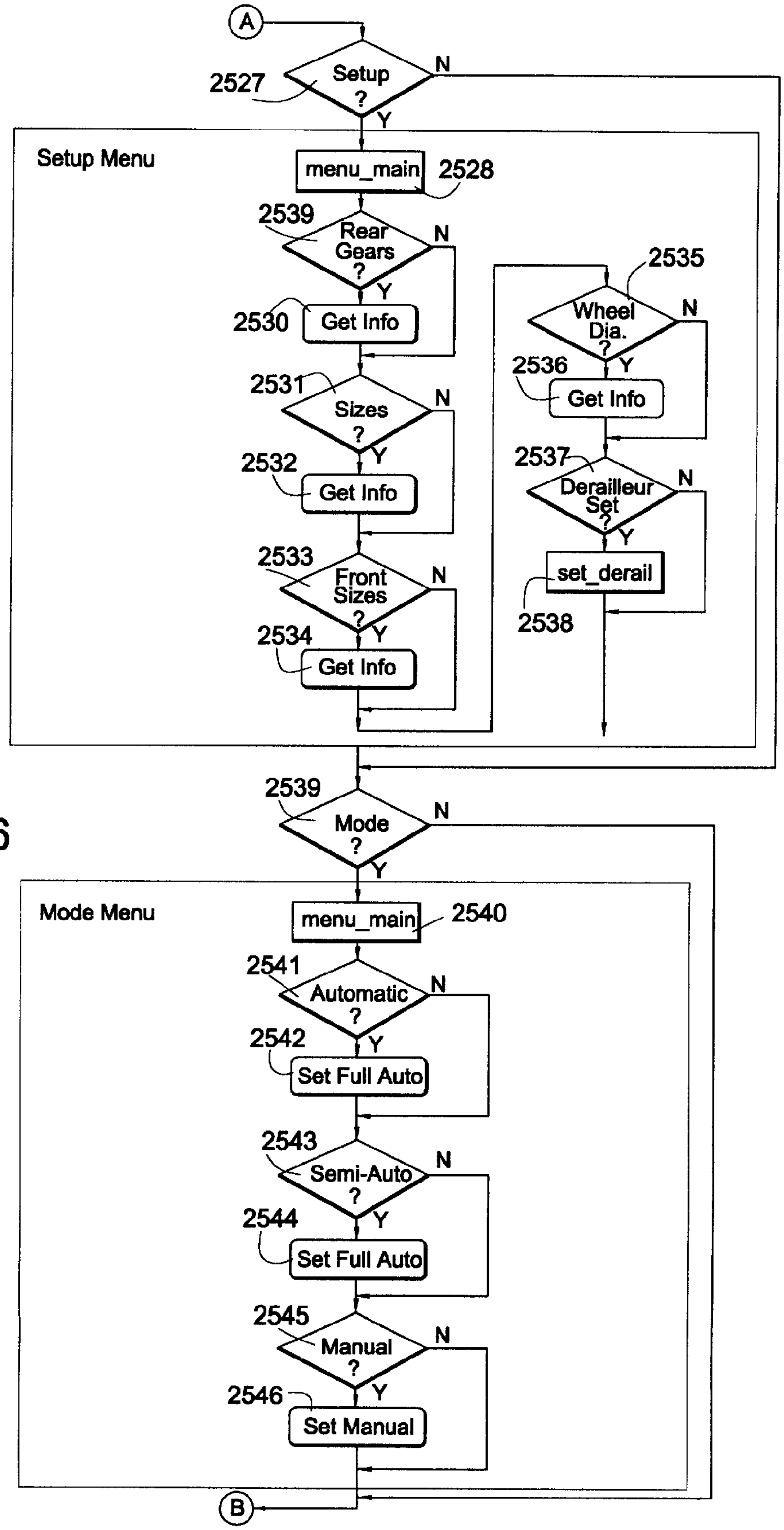

A
Setup ?
2527
N
Y
Setup Menu
menu_main
2528
2539
Rear Gears ?
N
Y
2530
Get Info
2531
Sizes ?
N
Y
2532
Get Info
2533
Front Sizes ?
N
Y
2534
Get Info
2535
Wheel Dia. ?
N
Y
2536
Get Info
2537
Derailleur Set ?
N
Y
set_derail
2538
2539
Mode ?
N
Y
Mode Menu
menu_main
2540
2541
Automatic ?
N
Y
2542
Set Full Auto
2543
Semi-Auto ?
N
Y
2544
Set Full Auto
2545
Manual ?
N
Y
2546
Set Manual
B

FIG. 26

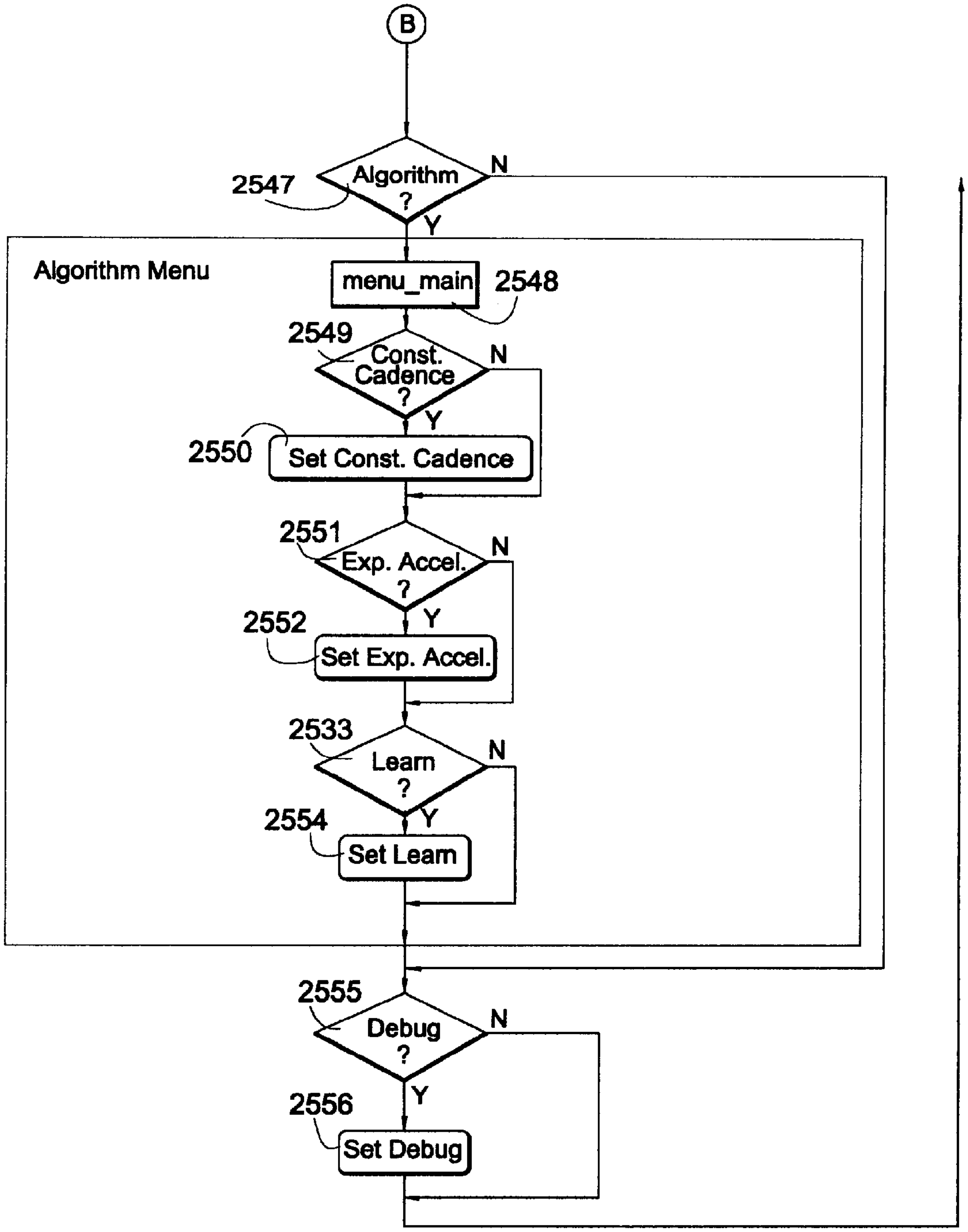

B
2547
Algorithm ?
N
Y
Algorithm Menu
menu_main
2548
2549
Const. Cadence ?
N
Y
2550
Set Const. Cadence
2551
Exp. Accel. ?
N
Y
2552
Set Exp. Accel.
2533
Learn ?
N
Y
2554
Set Learn
2555
Debug ?
N
Y
2556
Set Debug

FIG. 27

AUTOMATIC BICYCLE TRANSMISSION

CROSS-REFERENCE TO PROVISIONAL APPLICATION

The present application is related to provisional application 60/012,377, entitled "A COMPUTER CONTROLLED AUTOMATIC TRANSMISSION SYSTEM FOR A BICYCLE," filed Feb. 27, 1996, and which is incorporated by reference herein.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a transmission system for a human-powered vehicle. More particularly, the present invention relates to an automatic transmission system for a human-powered vehicle, such as a bicycle.

2. Description of the Related Art

Human-powered vehicles, such as bicycles, are usually equipped with multi-geared transmission systems that are shifted between incremental gear ratios for making changes in torque applied to the rear wheel, thus providing a vehicle operator with a plurality of possibilities for achieving a desired pedalling cadence and riding speed. The need for multi-geared transmission systems for bicycles and other human-powered vehicles arises from a variety of riding environments combined with different riding styles. For example, a racer tackles hills in a much different way than a rider out for an afternoon tour or a bicycle commuter on the way to work.

While some cyclists prefer manually shifting bicycles transmissions, other cyclists are concerned only with experiencing an enjoyable ride and do not want the burden of gear shifting decisions and manipulations. The latter type of cyclist, and those cyclists who have not learned how to shift properly, may easily cause damage to a bicycle and its transmission. More importantly, the ride experience for these types of cyclist turns out to be rough and uncomfortable.

A variety of shifting systems, some including programmable microprocessors, have been developed for addressing these problems. For example, U.S. Pat. No. 5,261,858 to Browning discloses a shifting system that does not allow shifting when a cyclist is not pedaling. The Browning system has the disadvantage that after a cyclist coasts to a quick stop, the transmission may be left in a high gear ratio. Since the system does not allow shifting when the cyclist is coasting, it is difficult for the cyclist to resume pedaling.

U.S. Pat. No. 5,213,548 to Colbert discloses a shifting device that has a limited number of inputs to the microcontroller of the device. Shifting decisions are made on wheel speed and cadence alone without the benefit of any other relevant information, when in reality, upcoming terrain has a large impact upon a cyclist's shifting decisions.

U.S. Pat. No. 5,356,348 to Bellio discloses a system that provides a constant cadence function, but requires a cyclist to choose from a preset, unchangeable range of cadence values that, once set, are not conveniently changed.

U.S. Pat. No. 5,254,044 to Anderson discloses a system that relies upon a timed actuation of multiple switches for successfully programming the system. A cyclist may become frustrated with the operation of the device and may decide to stop using it altogether.

Although prior systems are reliable and effective in many respects, they offer limited flexibility and provide operating modes having few features. What is needed is a bicycle

transmission system that adapts to the style of a cyclist instead of the forcing of the cyclist to adjust to the system; that utilizes information related to the riding environment and the cyclist's conditioning in making shifting decisions; that is easier to use than existing systems; and that is more effective than previous systems for increasing a cyclist's efficiency and safety.

SUMMARY OF THE INVENTION

The present invention provides a bicycle transmission system that adapts to the style of a cyclist instead of using a shifting algorithm that predefines shifting decision points and requires the cyclist to adapt to the shifting decision points. The present invention learns a cyclist's riding style and sets up shifting decision points based on the cyclist's style. By manually shifting the transmission over a typical riding course, the system records operating parameters associated with a set of desired shifting decision points, and then automatically shifts gears when similar situations are again encountered.

The present invention incorporates artificial intelligence for supplementing human intellectual abilities and uses a variety of information regarding the operating environment for automatically shifting a multi-geared variable transmission. Instead of requiring a rider to mentally recognize that the rate the rider is pedalling is too hard or too fast, the present invention recognizes such conditions and makes appropriate gears shifts making cycling more efficient. Thus, a ride becomes more enjoyable and, combined with the ease of use of the present invention, a cyclist is encouraged to ride more often.

A ratcheting front chain ring allows shifting to occur whenever the bicycle is in motion, providing significant improvement over conventional constant cadence systems that require a cyclist to pedal the crank for the system to shift. The present invention allows a cyclist to resume pedaling, even after coasting to a stop, without waiting for the shifting system of the present invention to readjust itself. In this way, the rider is provided with a confident, quick start from a traffic light, stop sign, or after a sudden emergency stop.

Since most ride displeasure for a rider and the most harm to a bicycle transmission is caused when the transmission shifts while the chain is under heavy tension, the present invention prevents such a situation from occurring. The amount of tension on the chain preventing a shift is determined by the cyclist so that the present invention can be customized to the style of the cyclist.

A microcontroller selectively considers information such as information relating to wheel speed, cadence rate, chain tension, cyclist effort and cyclist heart rate when making shifting decisions. In addition to customized automatic modes of operation in which shifting decisions are selectively based on constant cadence, constant (pedalling) force or exponential acceleration, a fully manual mode of operation and a full manual override for each automatic mode can be selected by a cyclist.

The present invention can be easily incorporated into bicycle frames and transmission, or retrofitted into existing frame and transmission designs. The present invention provides an effective technique for improving cycling efficiency, while minimizing additional mechanical components that adversely impact system weight and complexity.

The advantages of the present invention are provided by a gear shifting system for a human-powered chain- or belt-driven vehicle, such as a bicycle. The gear shifting

system includes a wheel speed sensor, a cadence sensor, a gear changer position sensor, a tension sensor, a clinometer, a controller and a gear changer actuator. The wheel speed sensor senses a speed of a wheel of a human-powered vehicle, while the cadence sensor senses a drive rate that a torque drive member of the vehicle drives a torque-transmitting member the vehicle, such as a rate of rotation of a crank of a bicycle. The gear changer position sensor senses a position of a gear changer of the vehicle, such as a derailleur or a multi-speed hub gear changer, with the gear changer positioning the torque-transmitting member, such as a chain or a belt, with respect to a plurality of gears of the vehicle. The tension sensor senses a tension of the torque-transmitting member that is transmitting a torque from the torque drive member to a gear of the plurality of gears. The clinometer senses an inclination of the vehicle. The controller generates a control signal based on the sensed wheel speed, the sensed drive rate, the sensed tension of the torque-transmitting member, the sensed vehicle inclination, the sensed gear changer position. The gear changer actuator is coupled to the gear changer and positions the gear changer with respect to the plurality of gears in response to the control signal.

The controller is inhibited from generating the control signal when the speed of the wheel is increasing and the tension of the torque-transmitting member is determined to be greater than a predetermined tension. The gear shifting system further includes a shift-down switch and a shift-up switch. Accordingly, the controller is responsive to actuation of the shift-down switch by generating the shift-down signal, and is responsive to actuation of the shift-up switch by generating the shift-up signal. A display device can be used for displaying at least one of a speed related to the sensed wheel speed, the sensed drive rate, and an indication of the sensed gear changer position with respect to the plurality of gears. The controller can also be configured for generating the control signal based further on an effort of a user of the vehicle, with the effort being proportional to an average sensed tension of the torque-transmitting member during a predetermined period of time, such as one crank revolution.

Preferably, the control signal includes a shift-down signal and a shift-up signal. The gear changer actuator moves the gear changer in response to the shift-down signal for decreasing a gear ratio of the vehicle, and moves the gear changer in response to the shift-up signal for increasing the gear ratio of the vehicle. According to the invention, a Boolean value of chain tension is determined based on a comparison of the sensed wheel speed and the sensed drive rate. Alternatively, the sensed tension of the torque-transmitting member is determined by comparing a product of a current gear ratio and the sensed wheel speed to the sensed drive rate.

A heart rate monitor can be used for sensing a heart rate of a user of the vehicle, in which case the controller generates the control signal further based on the sensed heart rate of the user. When the sensed user heart rate is less than a first predetermined heart rate, the controller generates a shift-up signal, and when the sensed user heart rate is greater than a second predetermined heart rate, the controller generates a shift-down signal. Preferably, the second predetermined heart rate is greater than the first predetermined heart rate. According to the invention, a target heart rate is stored in a memory. The first predetermined heart rate is less than the target heart rate by a predetermined difference and the second predetermined heart rate is greater than the target heart rate by the predetermined difference.

When the sensed drive rate is less than a first predetermined drive rate, the controller is enabled for generating a shift-down signal, and when the sensed drive rate is greater than a second predetermined drive rate, the controller is enabled for generating a shift-up signal. Preferably, the second predetermined drive rate is greater than the first predetermined drive rate.

According to another aspect of the invention, a gear shifting system for a human-powered vehicle, such as a bicycle, includes a tension sensor, a controller, and a gear changer actuator. The tension sensor senses a tension of a torque-transmitting member of the human-powered vehicle. The torque-transmitting member transmits a torque applied to a torque drive member of the vehicle to a gear of a plurality of gears. The controller generates a control signal based on the sensed tension of the torque-transmitting member. The gear changer actuator is coupled to a gear changer of the vehicle and moves the gear changer in response to the shift control signal and repositions the torque-transmitting member with respect to the plurality of gears.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and not limitation in the accompanying Figures in which like reference numerals indicate similar elements, and in which:

FIG. **1** shows an exemplary bicycle equipped with an automatic transmission system according to the present invention;

FIG. **2** shows a schematic functional block diagram of an automatic transmission system according to the present invention;

FIG. **3** shows a side conceptual view of a derailleur mechanism according to the present invention;

FIG. **4** shows a bottom conceptual view of a derailleur mechanism according to the present invention;

FIG. **5A** shows a top view of a derailleur mechanism in relation to a bicycle fixed gear set according to the present invention;

FIG. **5B** shows a side view of a derailleur mechanism in relation to a bicycle fixed gear set according to the present invention;

FIG. **6** shows a chain tension sensor according to the present invention;

FIG. **7** shows a ratcheting front crank according to the present invention;

FIG. **8** is a bottom view of a bottom bracket portion of a bicycle showing the physical relationship of the crank sensors according to the present invention;

FIG. **9** is a cross-sectional view along line A—A in FIG. **8** showing the physical relationship of the crank sensors according to the present invention.

FIG. **10** is a schematic block diagram of the processor circuit of the present invention;

FIG. **11** is a schematic diagram showing connections for a display connector according to the present invention;

FIG. **12** is a schematic diagram for a power supply circuit according to the present invention;

FIG. **13A** shows a schematic diagram for a motor drive according to the present invention;

FIG. **13B** shows a schematic diagram for a derailleur position switch sensor circuit according to the present invention;

FIG. **14** shows a schematic block diagram for a display and keyboard circuit according to the present invention;

FIG. 15 shows a schematic diagram for a magnetic pickup signal interface circuit according to the present invention;

FIG. 16 shows a system functional block diagram according to the present invention;

FIG. 17 shows a schematic block diagram for the hardware interface according to the present invention;

FIG. 18 shows a functional block diagram of the software modules of the present invention;

FIG. 19 shows a functional block diagram for the derivation module of the present invention;

FIG. 20 shows a functional block diagram for the algorithm module of the present invention;

FIG. 21 shows a flow diagram for the manual shift module of the algorithm module of the present invention;

FIG. 22 shows a flow diagram for the constant cadence module of the algorithm module according to the present invention;

FIG. 23 shows a flow diagram for the inhibit module of the present invention;

FIG. 24A shows a flow diagram for the logic module of the ratio control module of the present invention;

FIG. 24B shows a flow diagram for the actuate module of the ratio control module of the present invention; and

FIGS. 25, 26 and 27 show an exemplary flow diagram for the main user interface service loop according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows an exemplary bicycle **10** equipped with an automatic transmission system according to the present invention. While FIG. 1 shows the present invention adapted for operation with a bicycle, it should be understood that the present invention can also be used with other forms of human-powered chain- or belt-driven vehicles. Bicycle **10** includes a front wheel **11**, a rear wheel **12**, a crank or chainwheel **13**, a chain **14**, pedals **15**A and **15**B, a front derailleur **16**, a rear derailleur **17** and a gear set **18**.

Bicycle **10** is propelled in a well-known manner by applying a force to the pedals so that chain **14** acts as a torque-transmitting member by transmitting a torque generated at crank **13**, which acts as a torque drive member, to rear wheel **12**. Crank **13** includes at least one chainring, with each having a different number of teeth. For example, crank **13** has **2** chainrings, with one chainring having **52** teeth and the other chainring having **42** teeth. Gear set **18** includes a plurality of cogs that each have a different number of teeth. For example, gear set **18** has 6 cogs respectively having 13, 15, 17, 19, 21 and 23 teeth. Preferably, gear set **18** is a set of fixed cops, that is, gear set **18** does not freewheel. Chain **14** engages one of the chainrings and one of the cogs of gear set **18** in a well-known closed-loop manner. Derailleurs **16** and **17** are used for positioning chain **14** on a selected chainring and a cog of gear set **18**, respectively.

Many cyclists desire to pedal a bicycle at a constant cadence, that is, at a constant rate of rotation of crank **13**, or within a narrow range of cadences. Other cyclists may want a different riding parameter to take priority, such as riding at a nearly constant speed, or at a nearly constant heart rate. Selection of an appropriate chainring and a rear cog determines a suitable gear ratio for a particular riding condition and for achieving a desired riding parameter. Gear ratio for purposes of the present disclosure is defined as the number of revolutions of rear wheel **12** for each revolution of crank **13**. For example, the plurality of chainrings and rear cogs provides bicycle **10** with gear ratios ranging from 1.83 when chain **14** engages the 42-tooth chainring and the 23-tooth fixed cog, to 4.00 when the 52-tooth chainring and the 13-tooth rear cog are selected.

The present invention automatically selects a gear ratio based on detected riding conditions for achieving any one of a number of desired riding parameters. For example, if constant cadence is the desired riding parameter, the detected riding conditions are evaluated for automatically shifting to a suitable gear ratio for achieving a constant pedalling cadence. If constant torque (as manifested by constant effort) is the desired riding parameter, then bicycle **10** is automatically shifted to a gear ratio for achieving the desired torque. Similarly, if constant heart rate is desired, then the present invention automatically shifts bicycle **10** to an appropriate gear ratio for achieving the desired heart rate.

FIG. 2 shows a schematic functional block diagram of an automatic transmission system **20** according to the present invention. System **20** includes a controller **21**, a memory **22**, a wheel speed sensor **23**, a cadence sensor **24**, a front derailleur position sensor **25**, a rear derailleur position sensor **26**, a chain tension sensor **27**, a clinometer **28**, a shifter motor **29**, a power supply **30**, a display **31**, a shift-up switch **32** and a shift-down switch **33**. FIG. 1 shows preferred locations for the components comprising automatic transmission system **20**.

Controller **21** preferably is a readily available microcontroller having a suitable operating performance for providing the functions of the present invention. Controller **21** can physically include memory **22** or memory **22** can be physically separate from controller **21**, as indicated in FIG. 2. Memory **22** includes a non-volatile memory (ROM) portion **22**A, such as a read only memory (ROM) and/or an electronically alterable read only memory (EAROM), and a random access memory (RAM) portion **22**B. Non-volatile memory portion **22**A stores the program that controller **21** uses for determining whether a gear ratio shift is required. Non-volatile memory portion **23**A also stores default operating parameters use for determining gear shift points and for storing bicycle characteristics and user characteristics that are input by a user.

Wheel speed sensor **23** senses the speed of rear wheel **12** by sensing each occurrence of magnet M passing sensor **23**. Sensor **23** can also be positioned for sensing the speed of front wheel **11** with magnet M being attached to front wheel **11** accordingly. Cadence sensor **24** senses the drive rate of crank **13**, that is, the rate of rotation of crank **13**. Front derailleur position sensor **25** senses the position of front derailleur **16**. Similarly, rear derailleur position sensor **26** senses the position of rear derailleur **17** with respect to the plurality of gears of gear set **18**. Chain tension sensor **27** (FIG. 6) senses the tension of chain **14**.

Clinometer **28**, such as a plumb bob or capacitive clinometer, senses an inclination or pitch of the bicycle. Plumb bob-type clinometers include a weight on an arm that is connected to a variable resistor. Capacitive-type clinometers having a semiconductive fluid and air bubble positioned between 2 semispheres. The top sphere is etched with four metal triangular sections and the bottom is completely metalized. The capacitance between each of the triangles and the bottom varies as the bubble moves responding to the tilt of the clinometer. The output of clinometer **28** is converted to a usable signal, such as a PWM signal or a linear DC signal.

Controller **21** generates shift control signals that are based on the sensed wheel speed, the sensed crank rotation rate, the

sensed chain tension, the sensed bicycle inclination and sensed (front and rear) derailleur positions. A shifter motor **29** is coupled to rear derailleur **17**, and is responsive to a shift control signal by moving derailleur **17** for repositioning chain **14** with respect to the plurality of gears of gear set **18**. Similarly, a shifter motor is coupled to front derailleur **16** for repositioning chain **14** with respect to the plurality of chainrings of crank **13**.

FIGS. **3**, **4**, **5**A and **5**B show different views of a rear derailleur mechanism **17** according to the present invention. FIG. **3** shows a side conceptual view and FIG. **4** shows a bottom conceptual view of rear derailleur mechanism **17**. FIG. **5**A shows a top view and FIG. **5**B shows a side view of rear derailleur mechanism **17** in relation to gear set **18**.

In FIGS. **3** and **4**, rear derailleur mechanism **17** is shown mounted to the bicycle frame at the rear wheel hub **30**. Derailleur **17** includes a derailleur parallelogram **31** and an idler gear bracket **32** on which idler gears **33** and **34** are rotatably mounted. Pivot devices **35**, **36**, **44** and **45** allow derailleur parallelogram **31** and idler gear bracket **32** to operate so that idler gears **33** and **34** take up slack in chain **14** in a well-known manner as derailleur mechanism **17** is shifted through different gear ratios. A motor **37** is attached to derailleur **17** at an outer corner of parallelogram **31**. Motor **37** includes a shaft **38** on which a gear **39** is fastened. Gear **39** drives a gear **40** which is attached to one end of a shaft **41**. At the end of shaft **41** opposite gear **40**, shaft **41** has a threaded portion that is threaded through a threaded member **42**. Threaded member **42** is securely fastened to a corner of derailleur parallelogram **31** that is diametrically opposite the corner to which motor **37** is attached. A linear potentiometer **43** is aligned with shaft **41** and is used for sensing the relative position of motor and, hence, the rear cog that chain **14** is engaging.

A standard front derailleur **16** is adapted to work with the present invention by using a motor and a lead screw arrangement that functionally replaces the action of conventional front derailleur cable and which is configured similarly to the motor and lead screw arrangement used for rear derailleur **17**. Front derailleur position sensor **25** is a linear potentiometer that is used in a similar manner as linear potentiometer **43**.

FIG. **6** shows a chain tension sensor **60** according to the present invention. Chain tension sensor **60** includes a mounting surface **61** on which fixed sprockets **62** and **63** are rotatably mounted. Moving sprocket **64** is attached to mounting surface **61** through member **65** so that sprocket **64** moves parallel to a plane formed by surface **61** against a force provided by spring **66**. Member **65** is coupled to a linear potentiometer **64** so that an arm **67** makes an electrical contact with linear potentiometer **64**. Chain **14** is threaded between sprockets **62**, **63** and **64** so that as the tension of chain **14** varies, sprocket **64** moves against the force of spring **66** and changing the location of where arm **67** makes the electrical contact with potentiometer **64**. The relative position of arm **67** as it contacts potentiometer **64** is sensed and is proportional to the tension of chain **14**.

FIG. **7** shows a ratcheting front crank **13** according to the present invention. Ratcheting front crank **13** includes at least one chainring **71** having teeth (not shown). Chain **14** engages the teeth in a well-known manner for transferring a torque applied to front crank **13** via arms **13**A (FIG. **8**) and **13**C to rear wheel **12**. Front crank **13** also includes a freewheel mechanism **72** so that chainring **71** can continue to rotate when the bicycle is in motion and the rider is not pedalling. This action permits the present invention to shift while the rider is not pedalling because the chain is in motion whenever the bicycle is moving.

FIG. **8** is a bottom view of a bottom bracket portion of a bicycle showing the physical relationship of cadence sensor **24** (FIG. **2**) to crank **13**. FIG. **9** is a cross-sectional view along line A—A in FIG. **8** showing another view of the physical relationship of the crank sensors. FIGS. **8** and **9** show a sensor disk **80** mounted to crank arm **13**A using a clip pin **83** so that as bicycle **10** is pedalled, sensor disk **80** rotates uniformly around the rotational axis of crank axle **13**B. Sensor disk **80** includes a plurality of magnetic regions **81** that are regularly spaced around the outer edge of disk **80**. A sensor **82** is mounted to bicycle **10** so that sensor **82** detects magnetic regions **81** as magnetic regions **81** rotate around the rotational axis of crank axle **13**B. Sensor **82** includes two magnetic sensors, such as Hall effect sensors or coils of wire, that are arranged for detecting the rotation of crank **13**. Sensor **82** is connected to controller **20** through wires **84**, of which only a portion of wires **84** are shown in FIG. **9**.

FIGS. **10**–**15** show schematic block diagrams of controller **20**. The circuits shown in FIGS. **10**–**15** operate in a well-known manner. FIG. **10** is a schematic block diagram of the processor circuit portion **100** of controller **20**. Microprocessor **101** corresponds to controller **21** of FIG. **2**, and is preferably a suitable single chip micro-controller. Microprocessor **101** is connected to bus drivers **102**, **103** and **104**. Bus drivers **102**, **103** and **104** are each preferably 74LS244 bus drivers. FIG. **11** is a schematic diagram showing connections for a display connector P1. FIG. **12** is a schematic diagram for a power supply circuit portion **120** of controller **20**. FIG. **13**A shows a schematic diagram for a motor drive circuit portion **130**. FIG. **13**B shows a schematic diagram for a derailleur position sensor circuit portion **135**. Derailleur sensor circuit **135** corresponds to rear derailleur position sensor **26**, shown in FIG. **2**. FIG. **14** shows a schematic block diagram for a display and keyboard circuit portion **140** of controller **20**.

FIG. **15** shows a schematic diagram for a magnetic pickup signal interface circuit portion of controller **20**, corresponding to wheel speed sensor **27** shown in FIG. **2**. Circuit **151** is a magnetic pickup circuit for sensing speed of a wheel. Sensor L1, such as a Hall effect sensor or a coil of wire, is preferably mounted to bicycle **10** for sensing the speed of rear wheel **12** by sensing a magnet M attached to rear wheel **12**. Sensor L1 can also be mounted to bicycle **10** for sensing the speed of front wheel **11**. While only one magnet M (FIG. **1**) is shown attached to wheel **12**, any suitable number of magnets can be attached to wheel **12** and sensed by sensor L1. Amplifier U12A, preferably an LM**358**, amplifies wheel speed signals picked up by sensor L1. One input of an amplifier U12B, which is also preferably an LM**358**, is connected to the output of amplifier U12A. The other input to amplifier U12B is connected to a threshold setting potentiometer R13. Amplifier U12B is configured as a comparator so that when the output of amplifier U12A is greater than a threshold level set by potentiometer R13, amplifier U12B outputs a pulse signal that is applied to one input of NOR gate U11A. The other input of NOR gate U11A is connected to ground. NOR gate U11A outputs the wheel sense signal WHLSEN.

Magnetic pickup circuits **152** and **153** (sensor **82** in FIGS. **8** and **9**) for sensing rotation of crank **13** are configured the same as magnetic pickup circuit **151**, but only a single NOR gate U11B is used for generating the crank sensor signal CNKSEN. Magnetic pickup circuits **152** and **153** correspond to cadence sensor **24**.

FIG. **16** shows a system functional block diagram **160** of the present invention. The present invention includes a user interface portion **161**, a software portion **162** and a hardware portion **163**. When a heart rate monitor is used, the present invention includes a heart rate system **164**.

The user interface portion **161** provides an interface for inputting bicycle characteristics, user characteristics and dynamic user inputs. Bicycle characteristics include such characteristics as wheel diameter, gear ratios, gear positions and chain tension allowed. User characteristics include, for example, target cadence, a shifting algorithm selection, target heart rate (when a heart rate monitor is used), and cadence hysteresis. Dynamic user inputs that are provided through the user interface portion **161** are shift-up now, shift-down now and setup mode inputs.

Hardware portion **163** generates mechanical information, such as derailleur position information, wheel interrupt signals, cadence interrupt signals, clinometer signals and chain tension signals for input to the software portion **162**. The software portion **162** uses the inputs from the user interface portion **161** and from the hardware portion **163** for generating a derailleur actuator signal. When a heart rate monitor is used, heart rate monitor system **164** generates heart rate monitor signals that are input to the software portion **162**.

Heart rate monitor system **164** includes a sensor that is worn by a rider and produces a pulse signal, such as an RF pulse signal, at a frequency that is proportional to the heart rate of the rider. The frequency rate of the pulses are counted by controller **21** in a well-known manner and compared to two set points providing hysteresis around a target heart rate. The present invention adjusts the target heart rate over time to account for warm-up and cool-down intervals.

FIG. **17** shows a schematic block diagram for the hardware interface **163** according to the present invention. The hardware interface system includes an actuator system **171** having an actuator **172** and a derailleur position sensor **173**. Actuator **172** receives the actuator signal generated by software portion **162**. Derailleur position sensor **173** generates the derailleur position sensor that is used by software portion **162**. Wheel sensor system **174** generates wheel interrupt signal WHLSEN (FIG. **15**). Cadence sensor system **175** generates cadence interrupt signal CNKSEN (FIG. **15**). Clinometer sensor system **176** generates the clinometer signal and tension sensor system **177** generates the chain tension signal.

FIG. **18** shows a functional block diagram of the software modules that form of the software portion **162** of the present invention. A derivation module **181** receives the mechanical information generated by the hardware portion **163** and generates operating variables such as speed, pitch, tension, cadence, acceleration and effort. An algorithm module **182** receives the operating variables generated by derivation module **181**, user characteristic inputs and dynamic user characteristic inputs and generates ratio-up, ratio-down and force shifting signals. An inhibit module **183** uses the speed and tension operating variables generated by derivation module **181**, the dynamic user input setup mode and the force shifting signal generated by algorithm module **182** for determining whether shifting should be inhibited and generates an inhibit signal accordingly. Lastly, a ratio control module **184** using the inhibit signal generated by inhibit module **183**, the ratio-up and ratio-down signals generated by algorithm module **182**, the derailleur position information generated by hardware portion **163**, and gear position information input as a bicycle characteristic for generating an actuator signal and current ratio signal. The actuator signal is used for actuating a gear shift. The current ratio signal is input to algorithm module **182**.

FIG. **19** shows a functional block diagram for derivation module **181**. Derivation module **181** uses the wheel interrupt signal for generating a speed signal as:

$$Speed = \frac{\pi * (\text{wheel diameter}) * k_1}{(\text{IRQs/rev}) * (\text{time/IRQ}) * (\text{time/clock pulse})} \tag{1}$$

where wheel diameter is the diameter of the wheel, k_1 is the number of magnets attached to rear wheel **12** for sensing wheel speed, IRQs/rev is the number of wheel interrupt signals occurring for each wheel revolution, time/IRQ is the amount of time occurring between each wheel interrupt, and time/clock pulse is the amount of time occurring between each clock pulse.

Cadence is generated using the cadence interrupt signal CNKSEN as:

$$Cadence = \frac{k_2}{(\text{interrupts/rev}) * (\text{time/interrupt})} \tag{2}$$

where k_2 is the number of magnets used on sensor disk **80** for sensing cadence.

Acceleration is generated based on the wheel interrupt signal as:

$$Acceleration = \sum_{i=Time1}^{0} \frac{\left(\frac{S_{i-1} - S_i}{t_{i-1} - t_i}\right)}{Time_i - Time_{i-1}} \tag{3}$$

where S_{i-1} and S_i are the speed of the bicycle at the previous measurement point and the current measurement point, respectively. The summation of Equation (3) is made over the time interval of the last n wheel rotations. The variable n defines the size of a sliding window that is used for averaging out noise.

Chain tension is generated based on the chain tension signal using:

$$T = \sum_{i=Time1}^{0} \frac{Tension_i}{Time_i - Time_{i-1}} \tag{4}$$

where $Time_1$ is the time for one revolution of crank **13**.

Bicycle pitch is determined based on the clinometer signal and the acceleration signal as:

$$\text{Pitch} = \text{Clinosig} - \sin^{-1}(K_3 \cdot \text{Acceleration}) \tag{5}$$

where, Clinosig is the clinometer signal, and K_3 is an empirically determined compensation factor included for reflecting the mass (or fluid) inertia of the clinometer.

Effort is generated based on the chain tension signal as:

$$\text{Effort} = (\text{Tension}_{max} - \text{Tension}_{min})|_{Time_1} \tag{6}$$

where, Tension_{max} is the maximum chain tension and Tension_{min} is the minimum chain tension measured during time period $Time_1$ for one revolution of crank **13**.

FIG. **20** shows a functional block diagram for algorithm module **182**. Algorithm module **182** includes a manual shift module portion **201**, a constant cadence module portion **202** and an automatic module portion **203** providing artificial intelligence.

FIG. 21 shows a flow diagram for the manual shift module portion **201**. Module **201** is entered at **2101**. At **2102**, it is determined whether the shifting algorithm for a manual shift mode of operation has been selected by the user based on the shifting algorithm input. If not, the module is exited at **2107**. If so, flow continues to **2103** where it is determined whether a shift-up now input has occurred. If so, at **2104** a ratio-up signal is sent to ratio control module **184**, and module **201** is exited at **2107**. If not, flow continues to **2105**, where it is determined whether the user has entered a shift-down now command. If so, at **2106** a ratio-down signal is sent to ratio control module **184**, and module **201** is exited at **2107**. If not, module **201** is exited at **2107**

FIG. **22** shows a flow diagram for constant cadence module portion **202**. Module **202** are entered at **2201**. At **2202**, it is determined whether the shifting algorithm for a constant cadence mode of operation has been selected by a user based on the shifting algorithm input. If not, module **202** is exited at **2221**.

If the constant cadence shifting algorithm has been selected, flow continues to **2203** where it is determined whether the user has entered a manual shift-up now command. If a manual shift-up now command has been entered, flow continues to **2204** where a ratio-up output signal is generated and sent to ratio control module **184**. Flow continues to **2205** where an "up now" flag is set. Module **202** is then exited at **2221**.

If no manual shift-up now command has been entered, it is determined at **2206** whether a manual shift-down now command has been entered. If so, flow continues to **2207** where a ratio-down output signal is generated and sent to ratio control module **184**. Flow continues to **2208** where a "down now" flag is set. Module **202** is then exited at **2221**.

If no manual shift-down now command has been entered, flow continues to **2209** where it is determined whether an "up now" flag is set. If the "up now" flag is set, flow continues to **2210** where it is determined whether the cadence equals the target cadence. If not, the module is exited at **2221**. If so, flow continues to **2211**, where the "up now" flag is cleared. Flow continues to **2212**.

If the "up now" flag is not set at **2208**, flow continues to **2212**, where it is determined whether the "down now" flag is set. If the "down now" flag is set, flow continues to **2213** where it is determined whether the cadence equals the target cadence. If the cadence does not equal the target cadence, module **202** is exited at **2221**. If yes, flow continues to **2214**, where the "down now" flag is cleared. Flow continues to **2216**.

At **2216**, it is determined whether the cadence is greater than a target cadence based on inputs from **2215**. At **2215**, the target cadence used at **2216** is determined based on the target cadence input by the user, a cadence hysteresis, acceleration and effort values. If the cadence is greater than the target cadence, a ratio-up signal is sent to ratio control module **184** at **2216**, and module **202** is exited at **2221**. If not, flow continues to **2217**, where it is determined whether cadence is greater than the target cadence based on inputs from **2218**. At **2218**, the target cadence is determined based on the target cadence input by the user, the cadence hysteresis, acceleration and effort values. If so, a ratio-down signal is sent to ratio control module **184** at **2230**, and module **202** is exited at **2221**.

Automatic module portion **203** allows controller **21** to supplement human intellectual abilities. That is, instead of requiring a rider to mentally recognize that the rider is pedaling too hard or too fast, for example, automatic module portion **203** recognizes these kinds of conditions and makes appropriate decisions. Inputs that are relatively more important are recognized in a continually changing situation, and shifting decisions are made accordingly. The artificial intelligence feature of the present invention includes two aspects: parameters that are periodically stored in non-volatile memory, and decision making capability based on a plurality of conflicting inputs.

The artificial intelligence of the present invention uses a fuzzy rule-based system and can include neural networks to form an adaptive expert system. Preferably, the fuzzy rule-based system translates human experience directly into a programmable format instead of a computationally slow, statistical model. For example, instead of shifting when a rider's cadence exceeds 73.84 rpm exactly, controller **21** issues a shift decision when the rider is pedalling "too fast". Consider the problem of deciding how to increase a gear ratio after a rider crests the top of a hill. According to the invention, the appropriate decision making rule is formulated as: IF the cyclist's effort is decreasing rapidly AND the inclination angle is decreasing, THEN shift up a gear. "Rapidly decreasing effort" and "decreasing inclination angle" are fuzzy sets. The extent that each set is fulfilled is evaluated based on the effort and clinometer measurements. If the rider's efforts and vehicle inclination angle fall strongly within the "rapidly decreasing effort" and the "decreasing inclination angle", respectively, then a shifting decision is performed.

FIG. **23** shows a flow diagram for inhibit module **183**. The module is entered at **2301** and at **2302** it is determined whether the speed is less than a minimum threshold value. If so, module **183** is exited at **2307** with an inhibit signal being sent to ratio control module **184**. If the speed is not less than a minimum threshold, flow continues to **2303** where it is determined whether the setup mode is active. If so, module **183** is exited at **2307** with an inhibit signal being sent to ratio control module **184**. If not, flow continues to **2304** where it is determined whether shifting should be forced. If so, the module is exited at **2306** without an inhibit signal being generated. If not, flow continues to **2305** where it is determined whether the chain tension is greater than a preset tension threshold. If so, module **183** is exited at **2307** with an inhibit signal being generated. If not, module **183** is exited at **2306** without an inhibit signal being generated.

FIG. 24A shows a flow diagram for a logic module **2400** of ratio control module **184**. Logic module **2400** is entered at **2401** and at **2402** it is determined whether an inhibit signal has been sent to ratio control module **184**. If so, ratio control module **184** is exited at **2409**. If not, flow continues to **2403** where it is determined whether a ratio-up signal has been sent. If a ratio-up signal has been sent, flow continues to **2404** where it is determined whether the internally calculated ratio is less that the maximum ratio. Is it is, then flow continues to **2405** where the ratio is increased. If not, module **2400** is exited at **2409**.

If a ratio-up signal has not been sent, flow continues to **2406** where it is determined whether a ratio-down signal has been sent. If no ratio-down signal has been sent, module **2400** is exited at **2409**. If a ratio-down signal has been sent, flow continues to **2407** where it is determined whether the internally calculated ratio is greater than the minimum ratio. If it is, then flow continues to **2408** where the ratio is decreased. If not, module **2400** is exited at **2409**.

FIG. 24B shows a flow diagram for the actuate module **2410** of ratio control module **184**. Actuate module **2400** corresponds to the function of the increase ratio functional block **2405** and the decrease ratio functional block **2408** of ratio control logic module **184**. Actuate module **2410** is

entered at **2411**. At **2412**, it is determined whether the current derailleur position information is equal to the internally calculated gear position. If it is, actuate module **2410** is exited at **2416**. If not, flow continues to **2413** where it is determined whether the derailleur position information is less than the internally calculated gear position. Is it is, flow continues to **2414** where an actuate up signal is generated and the current gear value as a result of the actuate-up signal is calculated before module **2410** is exited at **2416**. If the derailleur position information is not less than the internally calculated gear position, the flow continues to **2415** where an actuate-down signal is generated and the current gear value as a result of the actuate-down signal is calculated before module **2410** is exited at **2416**.

FIGS. **25**, **26** and **27** show an exemplary flow diagram of the main user interface service loop **2500**. Interface service loop **2500** is entered at **2501** at power on-initialization where display **31** is actuated to momentarily display a power on/reset message. At **2502**, display **31** is cleared. At **2503**, the set up variables are set to their default settings and displayed. Display **31** is cleared at **2504**. Statistical values are calculated for bicycle characteristic inputs and user characteristic inputs that are stored in memory at **2505**. At **2506**, it is determined whether the bicycle is moving. If not, flow continues to **2507** where the system is shutdown for conserving the battery.

If the bicycle is moving, a key read module is entered by flow continuing to **2508** where it is determined whether the up key has been actuated. If yes, flow continues to **2509** where appropriate data is retrieved from memory for determining whether a shift should occur at **2510**. If a shift should occur, the derailleur motor is actuated at **2511**, display **31** is updated at **2512** and flow continues to **2508**.

If the up key is not actuated at **2508**, it is determined whether the down key has been actuated at **2513**. If it has, flow continues to **2514** where appropriate data is retrieved from memory for determining whether a shift should occur. If a shift should occur, the derailleur motor is actuated at **2515**, display **31** is updated at **2516** and flow continues to **2513**.

If the down key has not been actuated **2513**, flow continues to **2517** where the current gear ratio is returned. At **2518**, it is determined whether the mode key has been actuated. If not, flow continues to **2504**. If the mode key has been actuated, flow continues to **2519** where the up and down keys are read. At **2520**, it is determined whether the up key has been actuated. If yes, then the next menu is displayed on display **31**. Flow continues to **2519**. If the up key has not been actuated, flow continues to **2522** where it is determined whether the down key has been actuated. If so, the previous menu is displayed on display **31** at **2423** and flow continues to **2519**. If the down key has not been actuated, flow continues to **2514** where it is determined whether the enter key has been actuated. If not, flow continues to **2519**. If the enter key has been actuated, an object item number is returned at **2525** and at **2526** it is determined whether the main menu loop should be exited. If yes, flow continues to **2504**. If not, flow continues to **2527** (FIG. **26**), where it is determined whether the system setup containing information for the bicycle is to be changed.

If the system setup for the bicycle is to be changed, flow continues to **2528** where display **31** displays a setup menu. If not, flow continues to **2539**. From **2528**, flow continues to **2529**, where it is determined whether the rear gears are to be changed. If yes, flow continues to **2530** where the user is prompted for inputting information regarding the rear gears, and flow continues to **2531**. If the rear gear information is not to be changed, flow continues to **2531**, where it is determined whether gear size information is to be entered. At **2532**, gear size information is entered and flow continues to **2533**, otherwise flow continues from **2531** to **2533**. At **2533**, it is determined whether sizes of front gears is to be changed. If not, flow continues to **2535**. If the front gear information is to be changed, the information is entered at **2534**. Flow then continues to **2535**, where it is determined whether the wheel diameter information is to be changed. If so, the wheel diameter information is entered at **2536**, and flow continues to **2537**. If not, flow continues to **2537**, where it is determined whether the derailleur mechanism needs to be set. If so, flow continues to **2538** where the derailleur mechanism is set, and then to **2539**. If not, flow continues to **2539**.

At **2539**, it is determined whether the operating mode of the system is to be changed. If the operating mode of the system is not to be changed, flow continues to **2547**. Otherwise, flow continues to **2540**, where the mode menu is displayed. Flow continues to **2541**, where it is determined whether the automatic mode is to be set. If so, flow continues to **2542** where the automatic mode is set. Flow then continues to **2543**. If the automatic mode is not to be set, flow continues to **2543**, where it is determined whether the semi-automatic mode of operation is to be set. The semi-automatic mode of operation is a manual override of current automatically-determined parameters. The semi-automatic mode of operation is exited when sensors indicate that a higher or lower shiftpoint has been reached. If the semi-automatic mode of operation is to be set, flow continues to **2544** where the semi-automatic mode is set. Flow then continues to **2545**. If the semi-automatic mode is not to be set, flow continues from **2543** to **2545**. At **2545**, it is determined whether the manual mode of operation is to be set. If so, flow continues to **2546** where the manual mode is set. Flow then continues to **2547**. If not, flow continues around **2546** to **2547**.

At **2547**, it is determined whether the shifting algorithm is to be set. If not, flow continues to **2555**. If the shifting algorithm is to be set, flow continues to **2548** where the algorithm menu is displayed by display **31**. At **2549**, it is determined whether the algorithm is to be based on providing a constant cadence. If not, flow continues to **2551**. If the shifting algorithm is to be based on constant cadence, the constant cadence algorithm mode is set at **2550** and flow continues to **2551**. At **2551**, it is determined whether the shifting algorithm is to be based on an exponential acceleration. If so, flow continues to **2552** where the exponential acceleration mode is set, and flow continues to **2553**. If not, flow continues around **2552** to **2553** where it is determined whether a learning mode should be invoked.

The learning mode manifests itself in two forms. First, there is a direct mode in which a rider places the present invention in a learning mode, and manually shifts for allowing controller **21** observe and record the rider's preferences. Controller **21** returns to an automatic setting from the learning mode. For the second manifestation of the learning mode, supplementary learning occurs invisibly to the rider when controller **21** is in the automatic mode. Whenever the rider manually overrides a gear selection in the automatic mode, controller **21** records the manual gear selection and makes adjustments to the riding profile for reflecting the change in preference.

If a learning mode is not to be invoked, flow continues to **2555**. If the learning mode is to be invoked, flow continues to **2554** where the learning mode is invoked. Flow then continues to **2555**.

For troubleshooting purposes, the present invention includes a debug mode. Of course, production units of the present invention would not include the debug mode. At **2555**, it is determined whether the debug mode is to be entered. If not, flow continues to **2504**. If the debug mode is to be entered, flow continues to **2556** where the debug mode is entered for troubleshooting operation of the present invention in a well-known manner. Flow continues to **2504** upon exiting the debug mode.

While the present invention has been described in connection with the illustrated embodiments, it will be appreciated and understood that modifications may be made without departing from the true spirit and scope of the invention.

What is claimed is:

1. A gear shifting system for a human-powered vehicle, comprising:

a wheel speed sensor sensing a speed of a wheel of a human-powered vehicle;

a cadence sensor sensing a drive rate of a torque drive member of the vehicle drives a torque-transmitting member of the vehicle;

a gear changer position sensor sensing a position of a gear changer of the vehicle with respect to a plurality of gears of the vehicle;

a tension sensor sensing a tension of a torque transmitting member transmitting a torque from the torque drive member to a gear of the plurality of gears;

a clinometer sensing an inclination of the vehicle;

a controller generating a control signal to change the position of the gear changer with respect to the plurality of gears based on the sensed wheel speed, the sensed drive rate, the sensed tension of the torque-transmitting member, the sensed vehicle inclination and the sensed gear changer position, the controller being inhibited from generating the control signal when the speed of the wheel is increasing; and

a gear changer actuator coupled to the gear changer, the gear changer actuator positioning the gear changer with respect to the plurality of gears in response to the control signal.

2. The gear shifting system according to claim **1**, wherein the human-powered vehicle is a bicycle.

3. The gear shifting system according to claim **2**, wherein the

torque drive member is a crank, and the cadence sensor senses a rate of rotation of the crank.

4. The gear shifting system according to claim **3**, wherein the gear changer is a derailleur, and

the gear changer sensor senses the position of the derailleur with respect to the plurality of gears.

5. The gear shifting system according to claim **4**, wherein the torque-transmitting member is a chain, and

the tension sensor senses a tension of the chain.

6. The gear shifting system according to claim **1**, wherein the controller generates the control signal further based on an effort of a user of the vehicle, the effort being proportional to an average sensed tension of the torque-transmitting member during a predetermined period of time.

7. The gear shifting system according to claim **1**, wherein the control signal comprises a shift-down signal and a shift-up signal, the gear changer actuator positioning the gear changer in response to the shift-down signal for decreasing a gear ratio of the vehicle, and positioning the gear changer in response to the shift-up signal for increasing the gear ratio of the vehicle.

8. The gear shifting system according to claim **7**, wherein the sensed tension of the torque-transmitting member is based on a comparison of the sensed wheel speed and the sensed drive rate.

9. The gear shifting system according to claim **8**, wherein the sensed tension of the torque-transmitting member is determined by comparing a product of a current gear ratio and the sensed wheel speed to the sensed drive rate.

10. The gear shifting system according to claim **7**, wherein the tension sensor includes a displacement member that is displaced based on the tension of the torque-transmitting member.

11. The gear shifting system according to claim **7**, where the tension sensor includes a strain gauge that measures the tension of the torque-transmitting member based on a strain of the torque-transmitting member.

12. The gear shifting system according to claim **7**, wherein the controller is further inhibited from generating the control signal when the tension of the torque-transmitting member is greater than a predetermined tension.

13. The gear shifting system according to claim **12**, further comprising a shift-down switch and a shift-up switch, and

wherein the controller is responsive to actuation of the shift-down switch by generating the shift-down signal and is responsive to actuation of the shift-up switch by generating the shift-up signal.

14. The gear shifting system according to claim **12**, further comprising a heart rate monitor sensing a heart rate of a user of the vehicle, and

wherein the controller generates the control signal further based on the sensed heart rate of the user.

15. The gear shifting system according to claim **14**, wherein when the sensed user heart rate is less than a first predetermined heart rate, the controller generates a shift-up signal, and when the sensed user heart rate is greater than a second predetermined heart rate, the controller generates a shift-down signal, the second predetermined heart rate being greater than the first predetermined heart rate.

16. The gear shifting system according to claim **15**, further

comprising a memory, and wherein a target heart rate is stored in the memory, the first predetermined heart rate being less than the target heart rate by a predetermined difference and the second predetermined heart rate being greater than the target heart rate by the predetermined difference.

17. The gear shifting system according to claim **16**, further comprising a display device displaying at least one of a speed related to the sensed wheel speed, the sensed drive rate, an indication of a gear ratio, and the sensed user heart rate.

18. The gear shifting system according to claim **7**, wherein when the sensed drive rate is less than a first predetermined value, the controller is enabled for generating a shift-down signal, and when the sensed drive rate is greater than a second predetermined value, the controller is enabled for generating a shift-up signal, the second predetermined value being greater than the first predetermined value.

19. The gear shifting system according to claim **18**, wherein the

controller includes a memory, and wherein a target cadence rate value is stored in the memory, the first predetermined value being less than the target cadence rate value by a predetermined difference and the second predetermined value being greater than the target cadence rate value by the predetermined difference.

20. The gear shifting system according to claim **1**, wherein the controller generates the control signal using a fuzzy rule system that is based on the sensed wheel speed, the sensed drive rate, the sensed tension of the torque-transmitting member, the sensed vehicle inclination and a gear ratio as decision parameters.

21. The gear shifting system according to claim **20**, further comprising a heart rate monitor monitoring a heart rate of a user of the vehicle, and

wherein the decision parameters of the fuzzy rule system are further based on the sensed heart rate of the user.

22. The gear shifting system according to claim **21**, wherein the decision parameters of the fuzzy rule system are further based on an effort of the user of the vehicle, the effort being proportional to an average sensed tension of the torque-transmitting member during a predetermined period of time.

23. The gear shifting system according to claim **1**, wherein the controller includes a learning mode of operation, the controller generating the control signal based on the sensed wheel speed, the sensed drive rate, the sensed tension of the torque-transmitting member, the sensed vehicle inclination and the sensed gear changer position as decision parameters when in the learning mode of operation.

24. The gear shifting system according to claim **23**, wherein the decision parameters of the controller further include an effort of a user of the vehicle, the effort being proportional to an average sensed tension of the torque-transmitting member during a predetermined period of time.

25. The gear shifting system according to claim **1**, wherein the controller includes a memory, and

wherein the controller includes a learning mode of operation and a normal mode of operation, the controller accepting and storing user preferences for wheel speed,

drive rate, torque-transmitting member tension, vehicle inclination and the gear changer position in the learning mode of operation, and the controller generating the control signal based on the sensed wheel speed, the sensed drive rate, the sensed tension of the torque-transmitting member, the sensed vehicle inclination, the sensed gear changer position in the normal mode of operation.

26. A gear shifting system for a human-powered vehicle, comprising:

a wheel speed sensor sensing a speed of a wheel of a human-powered vehicle;

a tension sensor sensing a tension of a torque-transmitting member of the human-powered vehicle, the torque-transmitting member transmitting a torque applied to a torque drive member of the vehicle to a gear of a plurality of gears of the vehicle;

a controller generating a control signal based on the sensed wheel speed and the sensed tension of the torque-transmitting member, the controller being inhibited from generating the control signal when the speed of the wheel is increasing; and

a gear changer actuator coupled to a gear changer of the vehicle, the gear changer positioning the torque-transmitting member with respect to the plurality of gears, the gear changer actuator moving the gear changer in response to the control signal and positioning the torque-transmitting member with respect to the plurality of gears.

27. The gear shifting system according to claim **26**, wherein the human-powered vehicle is a bicycle.

* * * * *

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United States Patent [19]

Schwaller

[11] Patent Number: 5,247,430

[45] Date of Patent: Sep. 21, 1993

[54] LIGHT PLANT FOR BICYCLES INCLUDING A DYNAMO

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[73] Assignee: **Vereinigte Drahtwerke, A.G.**, Biel, Switzerland

[21] Appl. No.: **710,677**

[22] Filed: **Jun. 5, 1991**

[30] **Foreign Application Priority Data**

Jun. 7, 1990 [CH] Switzerland 1913/90

[51] **Int. Cl.**[5] **B62J 6/00**

[52] **U.S. Cl.** **362/72**; 362/183; 315/78

[58] **Field of Search** 362/72, 234, 276, 295, 362/183, 193; 315/78, 79; 320/9

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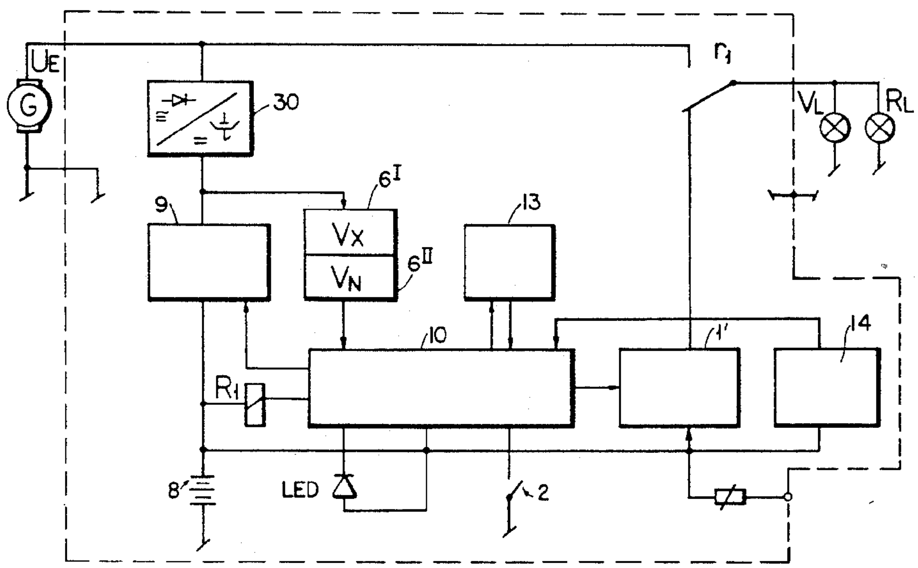
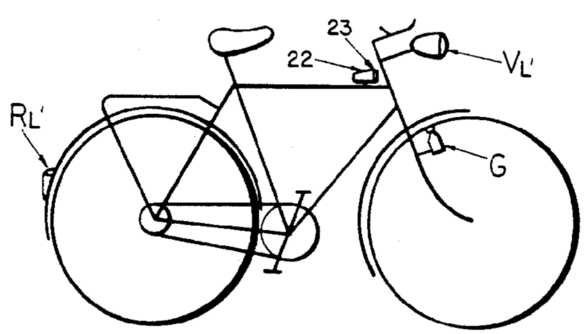
Primary Examiner—Stephen F. Husar
Attorney, Agent, or Firm—Ladas & Parry

[57] **ABSTRACT**

The bicycle light plant includes a front light and a rear light having a set rated voltage, which lights are connected via a current circuit to a dynamo. The current circuit includes a switching controller which lets the voltage of the dynamo pass uncontrolled if it is below the rated voltage of the bulbs and stabilizes the voltage upon reaching or exceeding, the rated value practically without losses onto voltage level corresponding to this rated value. Accordingly, overvoltage at the bulbs can be prevented. Possible excessive output is not taken from the dynamo or is used for charging of batteries.

7 Claims, 9 Drawing Sheets





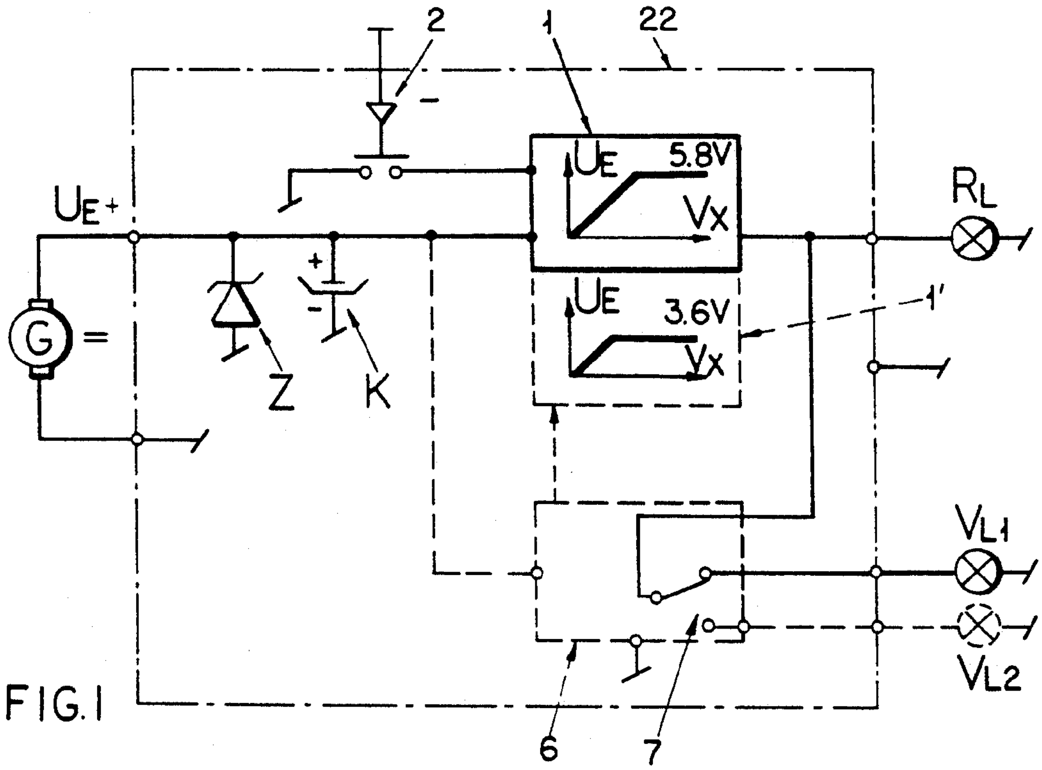


FIG. 1

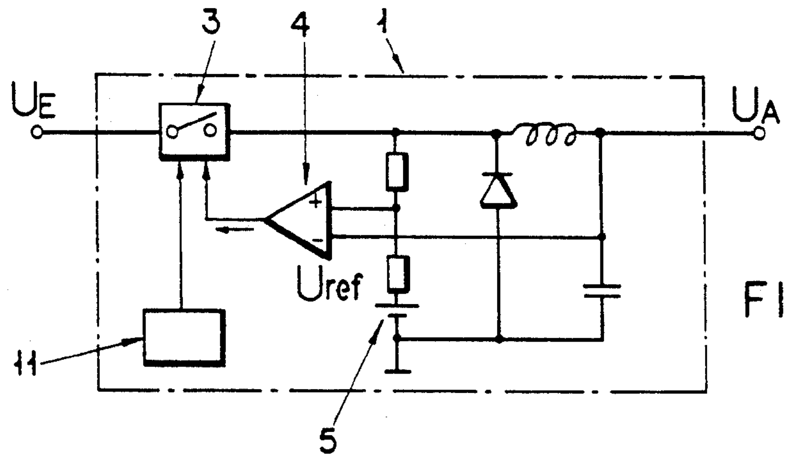
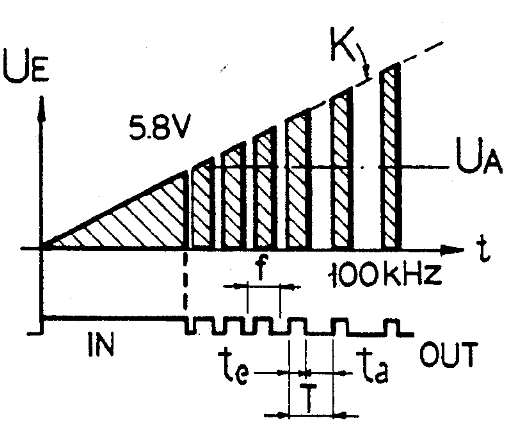


FIG. 2

FIG. 3



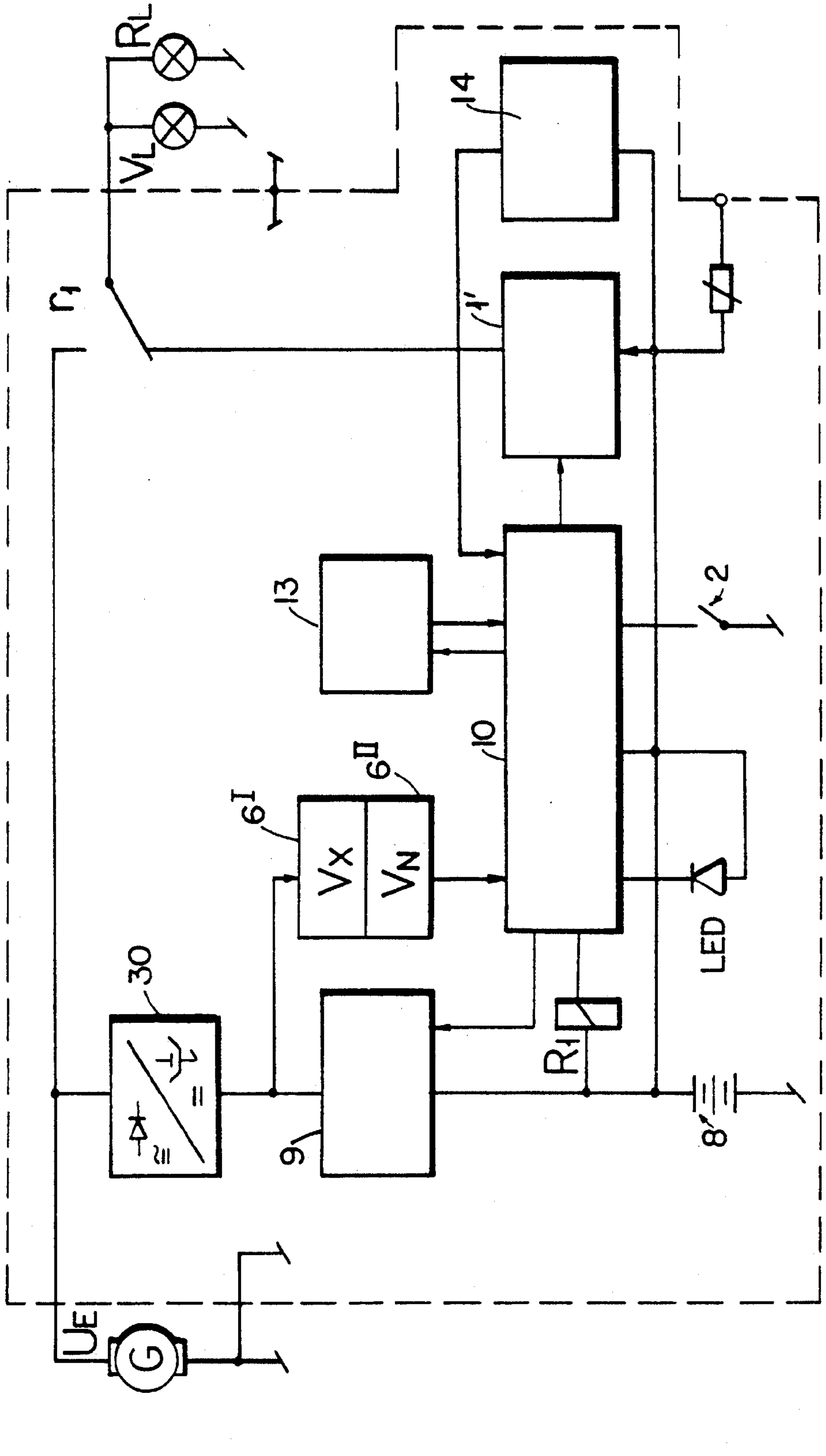


FIG. 4

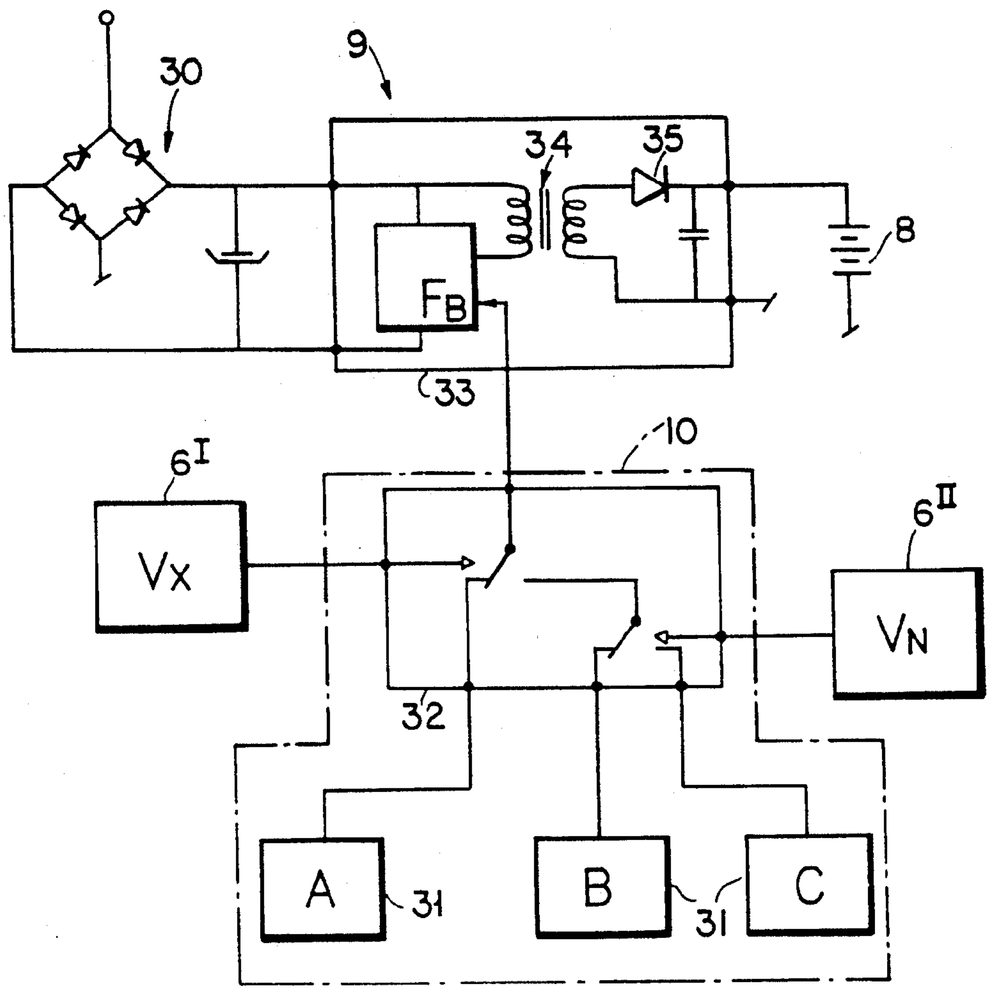


FIG. 5

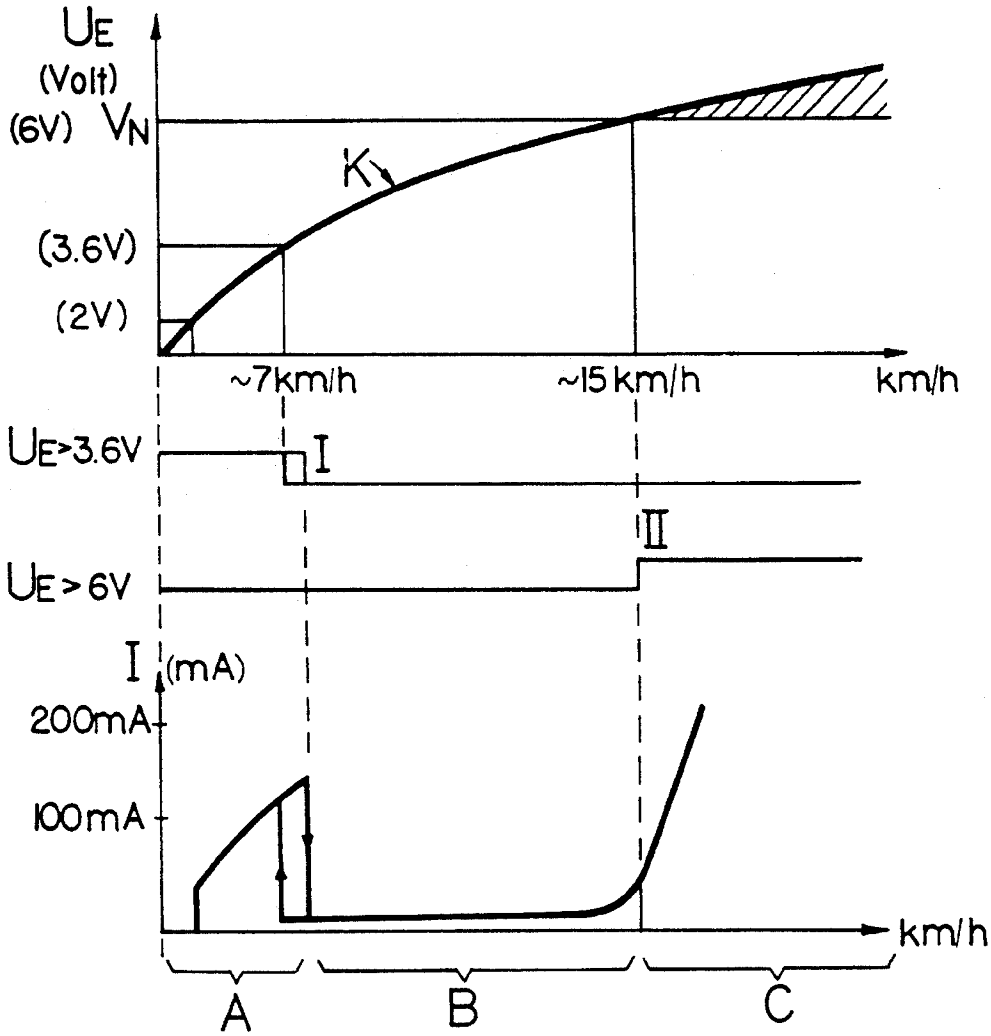
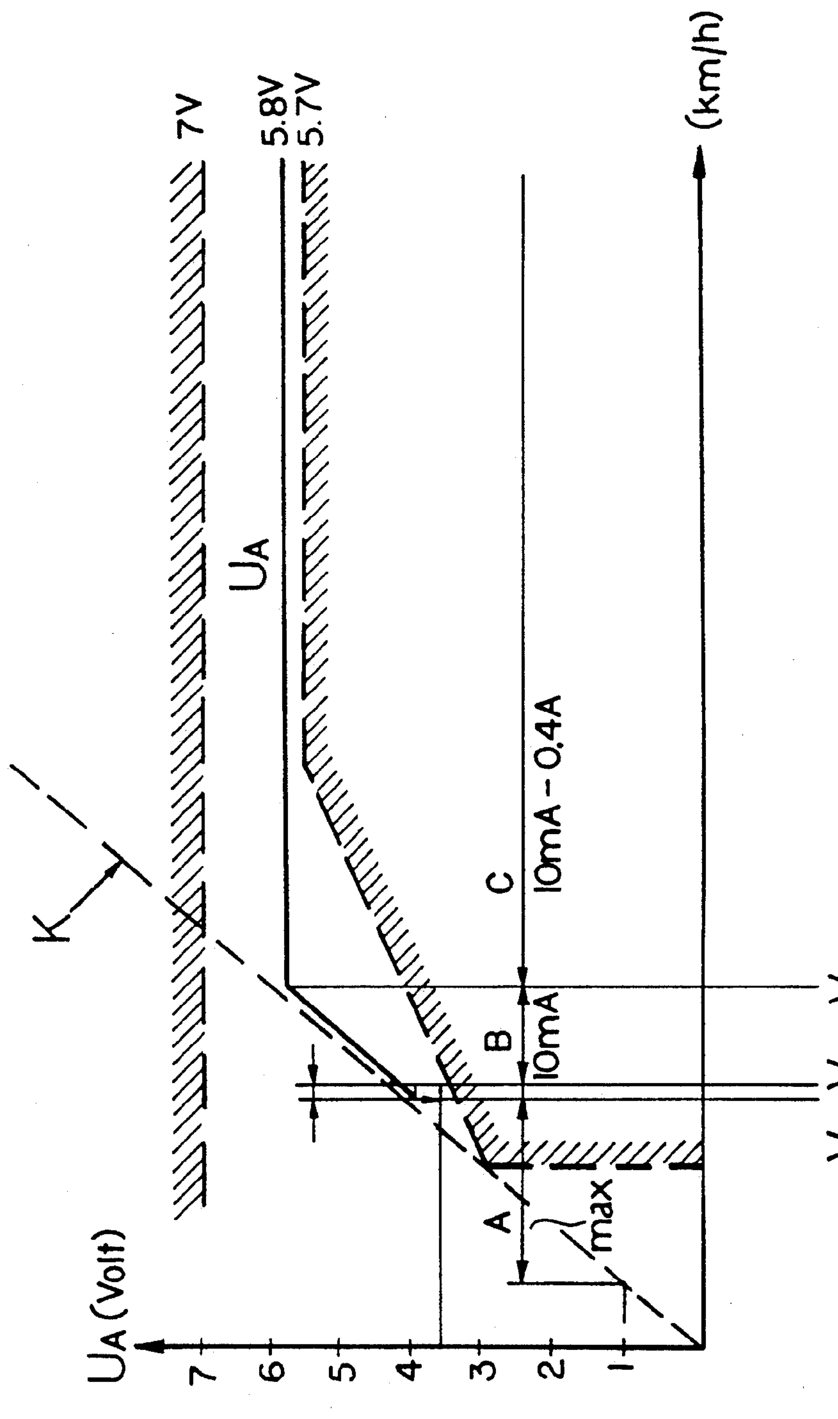

UE
(Volt)
(6V) VN
K
(3.6V)
(2V)
~7km/h
~15 km/h
km/h
UE>3.6V
I
II
UE > 6V
I (mA)
200mA
100mA
km/h
A
B
C

FIG. 6



U_A (Volt)
7V
5.8V
5.7V
(km/h)
U_A
K
C
10mA - 0.4A
B
10mA
A
max
V_N
V_{X1}
V_{X2}
7
6
5
4
3
2
1

FIG. 7

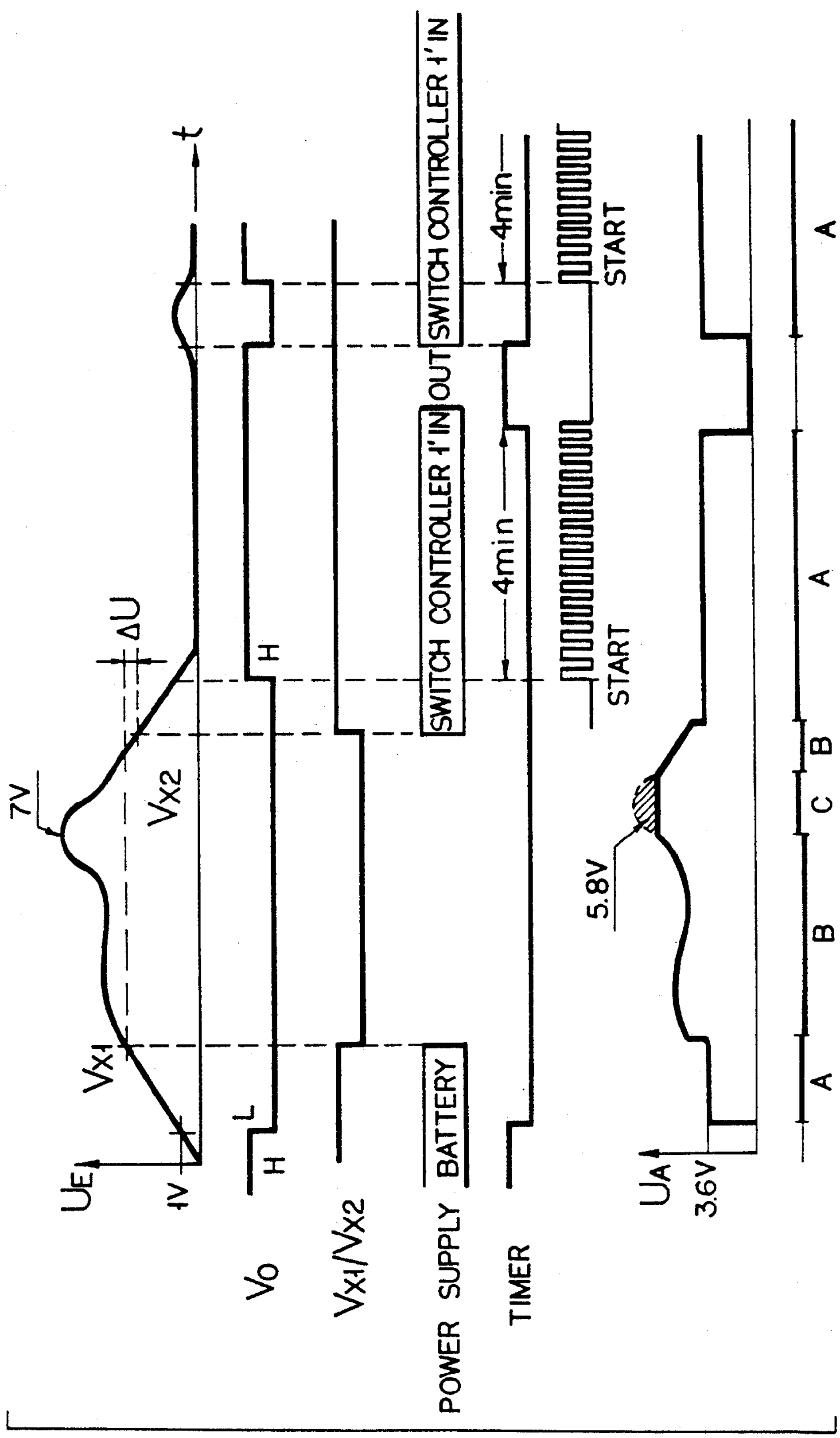

U_E
1V
7V
V_{X1}
V_{X2}
ΔU
t
V_0
H
L
H
V_{X1}/V_{X2}
POWER SUPPLY
BATTERY
SWITCH CONTROLLER 1' IN
OUT
SWITCH CONTROLLER 1' IN
TIMER
4min
4min
START
START
U_A
3.6V
5.8V
A
B
C
B
A
A

FIG. 8

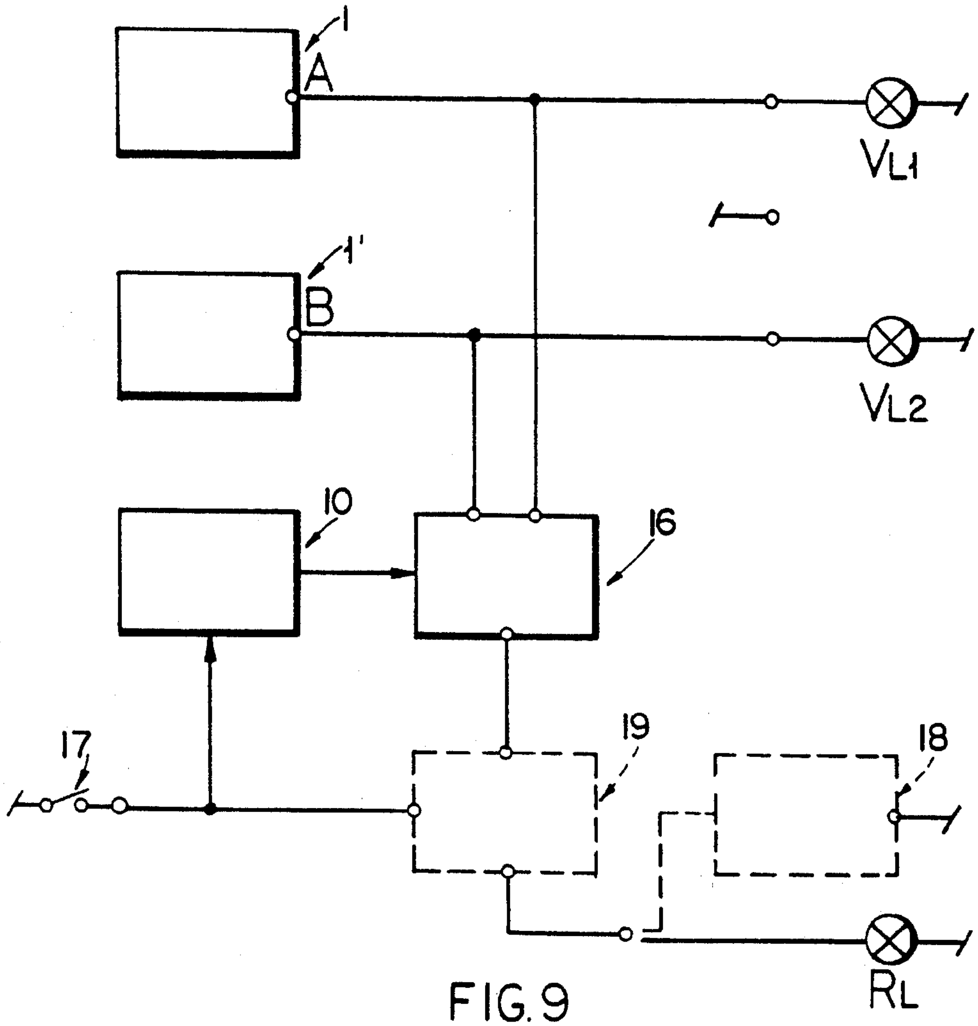


FIG. 9

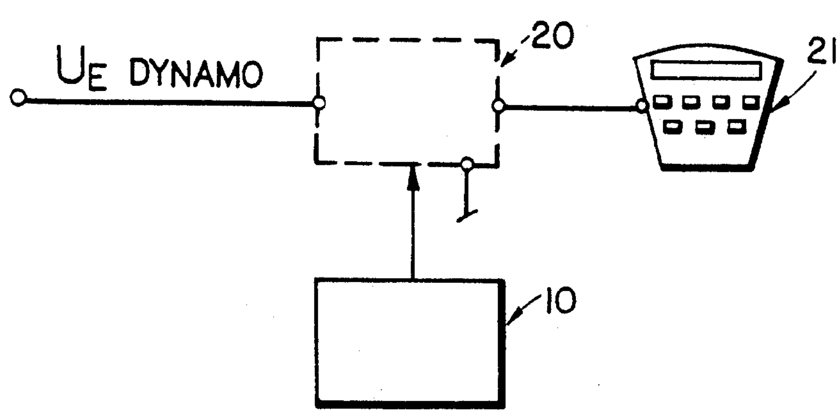


FIG. 10

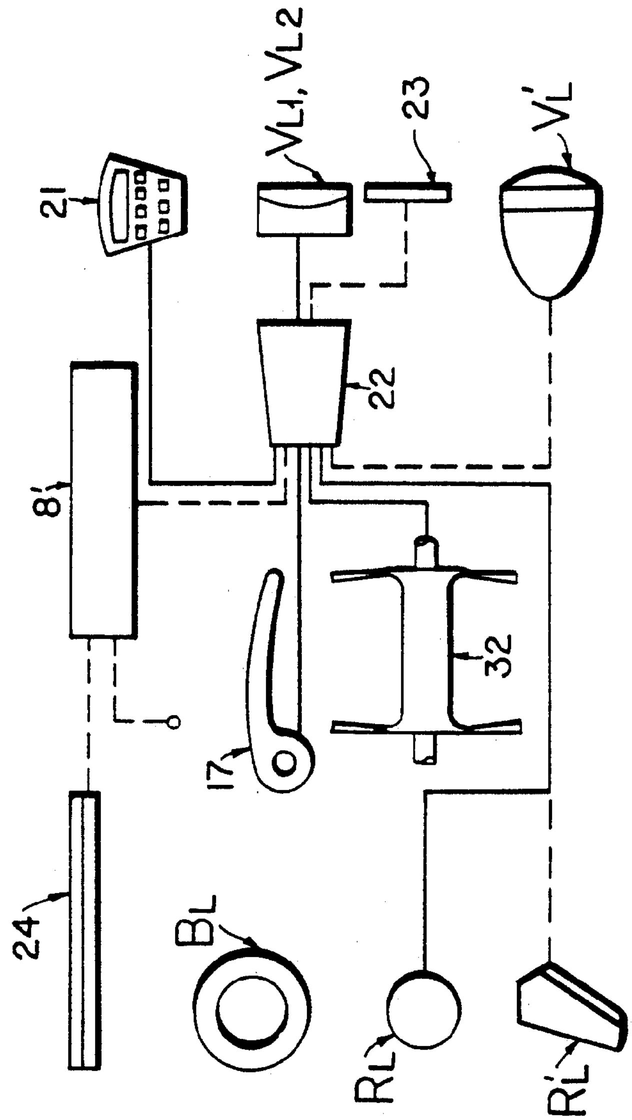


FIG. 11

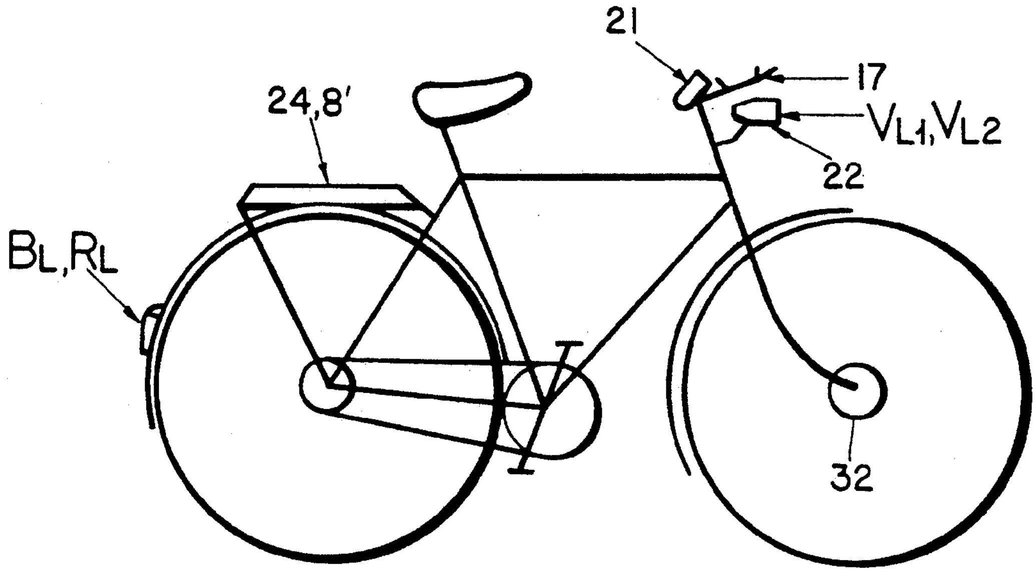


FIG. 12

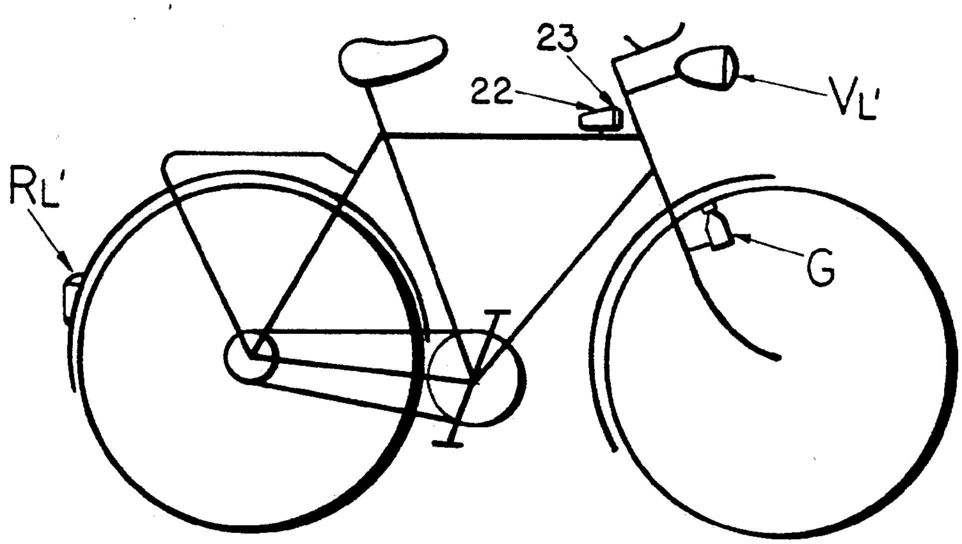


FIG. 13

LIGHT PLANT FOR BICYCLES INCLUDING A DYNAMO

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a light plant for bicycles having an electric circuit, which includes at least one front light, a rear light and a dynamo adapted to be driven by the bicycle, and a voltage limiting circuitry for the light voltage.

2. Description of the Prior Art

Such plants are known in a variety of designs, specifically also as parking light plants. In this respect attention is drawn to the German patent specifications DE-A 31 14 767 and DE-A-31 06 569. From these disclosures the problem relating to strongly fluctuating supply voltages and corresponding small or fluctuating light output of the bulbs operated thereby are known. In order to obviate these drawbacks electronically operating voltage and current limiting devices in the form of zener diodes have been proposed, by means of which harmful voltage peaks were not supplied to the bulb. On the other hand, it was foreseen in case of a supply by batteries to switch additional batteries in upon a decrease of the voltage. In these generally known plants it was necessary to limit the voltage to the lower level of the battery voltage, whereby in case of higher voltages the electrical power remained unused or was dissipated. This is inefficient, specifically if the light plant for bicycles shall also lend itself to be operated by rechargeable batteries.

SUMMARY OF THE INVENTION

Therefore, it is an object of the invention to provide a light plant for bicycles, in which at any operational condition an optimal light yield at all speeds can be combined with a minimal dynamo resistance and optimal charging conditions in case that rechargeable batteries are used such that the lifetime of the battery can be increased and generally the bulbs are protected.

A further object of the invention is to provide a light plant for bicycles, which lends itself to be designed based on the same basic circuitry of various modifications which are compatible with already existing parts of plants such that existing bicycles may also be equipped therewith.

Still a further object of the invention is to provide a light plant for bicycles, in which low inherent losses occur and which can be switched in such a way that in case of use of rechargeable batteries it runs continuously without substantially influencing the resistance against the movement or running.

Yet a further object is to provide a light plant for bicycles, which comprises at least one switching controller arranged between the dynamo and the front and the back lights, which switching controller is adapted to stabilize the voltage of the dynamo upon reaching or exceeding, a rated voltage of the lights substantially without any losses to a voltage level which corresponds to the rated voltage.

The use of a dynamo with an approximately linear characteristic in combination with a switching controller which stabilizes the voltage allows a specifically efficient operation of the bicycle light plant, in combination with a rechargeable battery or without such a battery.

By the stabilizing of the voltage to a predetermined level corresponding to the rated value of the lamps the excess output is not dissipated, it is rather not taken from the dynamo at all or then possibly used for the charging of batteries. Correspondingly, not only the voltage but also the resistance of the dynamo against rotation are stabilized to an optimal value.

The output voltage of the dynamo is measured by means of a threshold switch and converted into at least two, preferably three, switching states of the plant, which states each are adjusted optimally to the respective generated voltage.

The dynamo can be designed as a continuously running hub dynamo. The output generated therewith is sufficient at an optimal utilization for a running operation as well as for a parking light operation.

The bicycle light plant can be produced in various design modes, i.e. with one or two lamps for the front light, with or without rechargeable batteries and with or without any control logic such that it can be combined, depending on the design mode with generally available dynamos and lamps.

In one design mode a charging apparatus for the rechargeable batteries is switched via the control logic, depending on the prevailing running and operating state of the bicycle to various loading cycles. By each means, the charging procedure and the operating state of the lamps as well may be optimally adjusted to the running state such that during a normal, cyclic running behavior the running light and the parking light as well are guaranteed to be in a condition corresponding to legal standards.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood and objects other than those set forth above will become apparent when consideration is given to the following detailed description thereof. Such description makes reference to the annexed drawings, wherein:

FIG. **1** illustrates a base circuit for a first arrangement, whereby a second design embodiment is drawn with broken lines;

FIG. **2** is a schematic illustration of the circuitry of the switching controller of FIG. **1**;

FIG. **3** is a diagram illustrating the operation of the switching controller according to FIG. **2**;

FIG. **4** illustrates a circuit for a second arrangement having only one bulb in the front light and rechargeable batteries;

FIG. **5** is a block diagram of a part of the circuit in accordance with FIG. **4** in order to illustrate the charging controlling;

FIG. **6** is a diagram illustrating the switching conditions in dependence upon the speed;

FIG. **7** is a voltage-speed-diagram in accordance with FIG. **6**;

FIG. **8** is a speed-time-diagram of the circuit in accordance with FIGS. **4** and **5** for a running cycle;

FIG. **9** is a block diagram of a third arrangement in accordance with FIG. **4**, however with two different bulbs in the front light and further elements, such as a braking light;

FIG. **10** is a block diagram of an additional indicating device;

FIG. **11** illustrates an assembly of the components of a complete plant;

FIG. **12** illustrates a correspondingly equipped bicycle; and

FIG. 13 illustrates a bicycle, in which the plant is combined with generally available lamps and a generally available dynamo.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Firstly, the operation of a basic circuit of the light plant will hereinbelow be explained with reference to FIGS. 1 to 3. This basic circuit represents at the same time a first design mode of the plant.

The light plant comprises a generator G, designed as dynamo for a bicycle such as will be explained more in detail further below. This dynamo supplies after rectification a DC-voltage U_E or a DC-current, respectively, whose magnitude increases when the running speed of the bicycle increases. By means of a condensor K at the output side the output voltage U_E can additionally be smoothened and by means of a zener diode Z the electronics can be protected from an overvoltage.

The voltage-speed-characteristic curve K of the dynamo used (see FIG. 6) causes overvoltages to be generated at higher speeds, which would destroy the light bulbs of the bicycles and which would not correspond to the legal standards.

In accordance with the invention, however, it is specifically the generation of overvoltages which is used for a more efficient operation of the light plant. In order to achieve this, a switching controller 1 is switched in between the dynamo G and the lamps R_L (rear light) and V_{L1}, and V_{L2}, respectively, (front light), which switching controller 1 can be switched on and off via a switch 2. If it is switched off, the switching controller 1 acts as an opened switch and the bulbs are not connected to the dynamo G. If it is switched on, it stabilizes the voltage almost without any losses to a selectable value.

With reference to FIGS. 2 and 3 the operation of such a switching controller will be explained hereinbelow in an exemplary manner.

Up to a desired output voltage U_A (in the present example 5.8 V) an electronic switch 3 is continuously closed. The voltage of the dynamo can increase in this range without any losses until the desired output voltage U_A has been reached. If the voltage of the dynamo increases still further (FIG. 3), the electronic switch 3 is opened and again closed by an oscillator 11 in a set switching frequency of e.g. 100 KHz.

Thereby, the pulse duty factor te/T is changed as a function of the input voltage U_E and specifically such that the mean value of the voltage impulses which are led to pass through correspond to the stabilized output voltage U_A. At the same time a current limitation is also coupled therewith. The voltage impulses are converted in an LC-filter to a DC-voltage U_A. A corresponding control circuitry for the adjustment of the pulse duty factor by means of an operational amplifier 4 and of a reference voltage source 5 is illustrated in FIG. 2. The control amplifier is preferably designed according to a C-MOS-technique and operates at an efficiency more than 90%.

If the voltage U_E of the dynamo exceeds the desired output voltage U_A, the electrical output is accordingly not dissipated, the dynamo is rather relieved, wherewith also the electromotive force in the dynamo and accordingly the running resistance are correspondingly limited to an optimal value. If the dynamo G operates in this range, the bulbs of the front light and the rear light burn at a constant brightness. The nominal values for the lamps are e.g. 6 V/2.5 W for the front light and 6 V/0.6 W for the rear light, which values are tuned to this stabilized voltage.

If the running speed decelerates, a voltage is generated in dependence upon the speed which lies between 0 and 5.8 V. The more the voltage falls below the rated voltage of the bulbs, the less bright they burn. Accordingly, there exists the danger of a too weak light, and this specifically increased because the larger the deviation from the rated value of the lamps, the more the light yield decreases. In order to prevent such occurrence a threshold switch 6 is provided in a second design mode of the described plant (see FIG. 1 or 4), which senses the voltage of the dynamo. In the example of FIG. 1 completed by broken lines, the threshold switch 6 generates two states and the front light includes bulbs (or one bulb having two filaments) having differing nominal or rated voltages. The switch controller includes two stabilizing levels corresponding to these rated voltages. Hereinbelow these two levels are differentiated from each other by the identification switch controller 1 for the first and switching controller 1' for the second stage. If the voltage is below a value V_{X1} (=4.5 V in this example), it is stabilized by the switching controller 1' to 3.6 V and is connected via a switch 7 to the first bulb of the front light V_{L1} having a low rated voltage (in the example 3.6 V, 1 W). If the voltage exceeds the value V_{X1}, it is switched via the switching controller 1 to the second bulb V_{L2} which has the higher rated voltage (=6, V; 2.5 W in this example). If the voltage falls under a value V_{X2} (4.2 V in this example), the procedure runs in the opposite way. A hysteresis of about 0.3 V between the switching voltages V_{X1} and V_{X2} avoids a continuous switching and thus a flickering of the light in case the generated voltage of the dynamo fluctuates in the corresponding range.

If now two bulbs are used for the front light, it is possible to differentiate basically between three states of operation. If the voltage of the dynamo is in a range between 0 and 4.5 V, the voltage is stabilized at a low level, and the first bulb is operated at a low rated voltage, which secures in this range a good light yield. If the voltage of the dynamo exceeds the value 4.5 V, a switching over to the second bulb (or filament, respectively) is made and accordingly to the higher stabilized voltage level. Consequently an overvoltage at both bulbs is prevented in that a voltage limitation at their rated voltage is active for both.

In the range below the respective rated voltages the bulbs are operated at a fluctuating voltage of the dynamo, but yet at a relative good light yield.

In FIGS. 4 and 8 a further application of the principle of the circuitry is illustrated, whereby now the switching conditions which are adjusted to the voltage of the dynamo are not generated at the side of the bulbs, but rather at the side of the supply or the charging control, respectively, and are utilized for the stabilization of the voltage or optimal charging of a battery, respectively. Accordingly, in this embodiment rechargeable batteries 8 (with a rated voltage of 3.6 V) are provided at the feed side, which batteries 8 are connected via a battery charging converter 9, which is illustrated in detail in FIG. 5, to the dynamo G. The dynamo G has a voltage-speed-characteristic line K (FIGS. 6, 7). At the user side a front light V_L with only one bulb and one rear light R_L are provided, such that this plant can be operated with commonly available bicycle lights and bulbs.

In the here disclosed embodiment of the light electronics a differentiation between three operational states is made when the light is switched on, which operational states are hereinbelow identified by the letters A, B and C. In FIG. **6** these operational states are illustrated in dependence upon the speed of the bicycle. The first line in FIG. **6** depicts the voltage-speed-characteristic line K of the dynamo G. The second line depicts the switching over from the operational state A to the operational state B corresponding to the logic signal out of a first threshold switch 6^{I}. The third line represents the corresponding logic signal of a second threshold switch 6^{II}. Finally, at the lowermost line the charging current I for the battery **8** is depicted. The course of the output voltage U_A present at the bulbs can be seen in FIG. 7.

The operational state A is present at stand-still or at a slow speed (up to e.g. 7 km/h) as long as the output voltage of the dynamo G remains below a first threshold value I of e.g. 3.6 V. At the operational state A the energy for the lamps is taken from the battery **8**, and the energy of the dynamo generated is charged after a suitable DC/DC-conversion in the charging converter **9** to the battery **8**.

If threshold value I is exceeded by a higher speed, a switching over into the operational state B is made as long as the full bulb voltage has not been reached yet. In this range the charging converter **9** operates as constant-small-current converter for a generation of a constant charging current of about 10 mA for the battery **8**. This load corresponds roughly to the normal bulb-resistance tolerances and is thus allowable. It is, however, of importance for the battery **8** that it is also charged at the (most common) speed between about 6 to 14 km/h.

At speeds above about 15 km/h the voltage U_E of the dynamo exceeds the rated voltage of the bulbs of 6 V. Here now the operational state C is taken into operation as long as a threshold value II of about 5.8 V of the dynamo voltage is reached. In this operational state the electronics operate to hold the voltage constant because when the rated voltage of the bulbs is exceeded, the lifetime thereof decreases greatly. The excess dynamo energy is charged into the battery **8**. The charging current which is accordingly attainable can reach up to 250 mA (high speed-charging).

A corresponding design of a circuit is illustrated in FIG. **4**. The standard dynamo G is connected via a rectifier **30** with a filtering to the electronics. It includes on the one hand a threshold switch **6** having a first threshold value I of the voltage U_E of the dynamo at about $V_x=3.6$ V and a second threshold value II at about $V=5.8$ V. In FIGS. **4** and **5** the threshold-switch **6** is graphically separated correspondingly in two blocks. The threshold switch **6** determines the mentioned threshold values of te voltage of the dynamo and delivers corresponding control signals to a control logic **10**. This control logic **10** possesses three control circuits **31**, each of which is allocated to one of the mentioned operational states and accordingly are illustrated in FIG. **5** by corresponding blocks A, B, C. Depending upon the prevailing operational state one of these control circuits is connected via a logic **32** to the charge converter **9** and supplies corresponding control signals to same, such as can be seen in FIG. **5**.

The charge converter **9** is switched between the rectifier **30** and the battery **8** and possesses also a switching controller **33**, which receives via a feedback-input F_B the control signals of the control circuits **31**. The correspondingly controlled output signal of this switching controller is supplied via a transformer **34** and a rectifier arrangement (see FIGS. **1** to **3**) as DC-current to the battery **8**, as can be seen specifically in FIG. **5**.

At the operational state A the controlling of the load occurs by an adjustment of the resistance that such the energy of the dynamo present in this range is optimally charged into the battery **8**. The bulb receives thereby its energy completely from the battery, for which reason the voltage of the bulb does not fall below the voltage of the battery of 3.6 V. The control circuit **31** A operates in such a way that upon a reaching of the first threshold voltage I the load of the dynamo corresponds approximately to the load of the bulb (of about 12 Ω). This is in order to keep the switching over hysteresis ΔU during the switching over into the operational state B at a small value, such that no large fluctuation of the brightness in the bulbs V_L and R_L occurs.

The switching over from the operational state A into the operational state B proceeds via hysteresis, such as specifically illustrated in FIGS. **6** and **7**. The switching up from A to B proceeds at a somewhat higher voltage V_{x1} than the switching back from B to A at the lower voltage V_{x2}. By means of such a continuous switching back and forth in this range of the running and accordingly a flickering of the light can be prevented.

In the operational state B the bulb receives the current from the dynamo (FIG. **7**). Until the complete bulb voltage has been reached, it should not be loaded too strongly by the charging of the battery. In spite of this, it is important for the energy balance that a charging proceeds also in this range of speed which occurs often. As already explained, the switching controller **33** is, therefore, controlled by the control circuit B such that a small constant charging current of e.g. 10 mA is generated. Because this corresponds merely roughly to the standard bulb-resistance-tolerances, the light yield is not markedly negatively influenced by this.

If the rated voltage of the bulbs of 6 V is reached at speeds of about 15 km/h, the threshold switch 6^{II} switches the control circuit **31** C onto the charging converter **9**. This control circuit controls the loading of the dynamo in such a way, that a voltage of 6 V by means of the controller load is not exceeded in any case. The energy of the overvoltage is charged into the battery (see FIGS. **6** and **8**). When rolling downwards at a high speed it is thus possible to generate a charging current up to 250 mA and to achieve a high speed charging of the battery.

A switching controller **1'** is arranged between the battery **8** and the bulbs. It stabilizes the voltage and the current, respectively, from the battery **8** or from the charging converter **9**, respectively, which reaches the bulbs, to a value of e.g. 3.2 V, such that a constant brightness of the bulbs, which is positive for the safety, is secured. It becomes active in the operational state A at a low dynamo voltage.

When running with the dynamo and the light switched off (=charging) the circuit operates in the operational state A, i.e. the load of the dynamo corresponds to the load of the bulbs. The batteries are charged approximately by the energy which the bulbs would consume. The fully charged state is then detected by a battery control circuit **36** and indicated via the control logic **10** by means of a light emitting diode LED.

The light emitting diode indication allows the operator to recognize in any phase of the operation the state of the light plant. The indication proceeds for example as follows:

The diode is continuously lighted when the light is switched on and the capacity of the battery is between about 30% and 90%.

The diode flickers in a 1 Hz-cycle if the capacity of the battery falls during the running with light below about 30%.

The diode flickers at a 4 Hz-cycle if the light is switched off and the batteries are being charged until a battery capacity of about 90% is reached.

If the battery capacity is more than 90%, the LED-indication is inactive.

The battery control circuit **36** has, furthermore, a controlling function if the battery is present. If the battery **8** is not present or is largely discharged, this is determined by a presence-control-logic and stored in the control logic **10**. In this case the described electronics remains inactive. The bulbs V_L, R_L are in this case connected via a relay R_1, r_1 directly to the dynamo G (FIG. **4**). The battery charging converter operates in this case in the operational state B, i.e. it generates a small charging current. By means of such, a low discharging protection for the battery **8** on the one hand and a safeguarding of the running with light on the other hand is reached.

The control logic can be operated by means of the key **2**. If the key is depressed longer (longer than e.g. 0.25 sec), the memory in the control logic **10** can be set to "on", wherewith the light plant is switched on via the control logic **10**. If the key is depressed for a short time span (less than 0.25 sec), the memory is set to "off" and the plant is shut off. A parking light-time **13** is connected, furthermore, to the control logic **10**, whose function will be described further below.

An advantage of the described embodiment with battery support is the generation of the parking light. When the bicycle is stopped and accordingly the output voltage of the dynamo G falls to zero, the operational state of a battery supply at a voltage stabilized to 3.2 V occurs in accordance with the above description. Therefore, the light keeps on burning also at a reduced consumption in case it is switched on. If the voltage of the dynamo sinks below a minimal value Vo (of e.g. 1 V), this is determined by the threshold switch **6** and a signal for the control logic **10** is generated. This control logic **10** is connected to a timer circuit **13**, which starts in this instance and counts during a predetermined time T (of e.g. 4 min). During this time span the switching controller **1'** remains switched on and the light continues to burn. If the time is expired, the control logic switches the switching controller **1'** off and the light is switched off, although the on/off-memory is still in the state ON. If the dynamo generates again a voltage which exceeds Vo (=1 V) or if the key is operated longer than 0.3 sec, the timer circuit **13** is set back and the switching controller **1'** is switched on again, such that the light burns again stabilized at 3.2 V. By means of this switching on and switching off automatically, the parking light operation can be secured without any excessive consuming of the battery and without any special operation by the operator.

The described operational states are schematically combined in a plurality of diagrams belonging to each other in FIG. **8** to an arbitrary running profile.

As can be derived from this illustration, the bicycle light plant is designed such that at the side of the consuming and at the side of the supply as well a switching over between various operational states is made during the entire running cycle, of which states every one is optimally adjusted to the respective operational state. Consequently, it can be guaranteed that always an excellent light is available during normal running cycles, that the batteries are always charged and the resistance against the running remains limited.

Up till now plants have been described, in which alternatively it was only possible to switch between different operational states only at the side of the user or at the supplier side, which allows either the use of a common dynamo or of common bulbs, and now a plant is illustrated in FIG. **9**, in which a switching is made between the operational states at the supply side and at the user's side as well. Hereto reference can be made extensively to the above description, whereby each switching controller **1** or **1'** is connected with its own lamp (or filament, respectively) V_{L1} and V_{L2}, respectively, of the front light. Preferably halogen lamps having two filaments of a different rated output are used for the front light. For the rear light R_L, furthermore, a switch **16** is provided, which connects the respective active switch controller to the rear light. Otherwise the plant operates as described above with the difference that during the switching between the two switching controllers a voltage step from 3.6 V to about 4.5 V occurs because the light value of the bulb V_{L1} (3.6 V/1.2 W) corresponds roughly to the one of the bulb V_{L2} (6 V/2.5 W) at an operational voltage of 4.5 V. By means of such, no difference regarding brightness is discernible during the switching between the two bulbs (or filaments, respectively). Furthermore, a braking light function is indicated in FIG. **9**, which can be added to the rear light R_L. Hereto, on the one hand a brake contact **17** is provided in the area of the brakes and on the other hand a LED-rear light **18** is provided with two segments (see FIG. **11**). The one segment acts as rear light in the night and the other one as braking light. Both are supplied via the same wire, whereby the transmission of the braking light is modulated by an additional electronics **19** and is decoded in the braking light. By means of this arrangement the same supply can operate selectively the rear light and/or the braking light. The compatability with a normal rear light is thereby guaranteed.

Finally, FIG. **10** illustrates a control circuit **20** for an indicating and operating unit **21**, which is connected to the control logic **10**. It is possible to conclude from the measured dynamo-voltage U_E the speed, from which the covered distance etc. can be calculated and indicated by means of a time measurement.

The heretofore described bicycle light plant can be operated by commonly available dynamos G.

The described bicycle light plant is composed of a plurality of components, which depending on the design state of the plant, may be replaced partly by generally available components. The plant is illustrated in FIG. **11** in a general overview and with its components. FIGS. **12** and **13** illustrate correspondingly equipped bicycles. The central part of the plant is an electronics housing **22**, which contains the described electronics in the possible design modes. The electronics housing **22** acts preferably also as housing for the lamps of the front light in case it is equipped with two halogen lamps V_{L1}, V_{L2} (or one bulb having two filaments, respectively). If

the electronics is operated by a generally available front light V_L', it is possible to place a cover **23** onto the housing **22** in place of the light part. This is then mounted at a suitable location on the frame of the bicycle (FIG. **13**). Furthermore, a separate indicating unit **21** is provided, which is located in the field of vision of the driver (FIG. **12**) and which includes the described LED-indicators and switches **11**. The rechargeable batteries **8** are as a rule located in the electronics housing **22**. In case an additional battery **8'** or solar cells **24**, respectively, are used, there can be located at the area of the baggage rack (FIG. **12**). The electronics is connected to dynamo G, which e.g. may be a wheel hub dynamo. If a LED-rear light R_L together with a braking light B_L is used, this brake is correspondingly equipped with a feeler **17** for the braking light, which as has been described is connected to the electronics **22**. It is, however, also possible to use a common rear light R_L'.

A bicycle is illustrated in FIG. **12**, which is equipped with a completely equipped bicycle light plant having a hub dynamo **32**, electronics **22** with halogen bulbs V_{L1}, V_{L2}, built thereonto, indicating unit **21**, LED-rear light R_L and braking light B_L and solar cells **24**. The electronics corresponds to the one of FIG. **6**.

FIG. **13** illustrates in contrast thereto a bicycle plant in combination with a common front light V_L', common dynamos G and a common rear light R_L. The electronics corresponds thereby to the one of FIG. **4**.

As can be seen out of the above description, the bicycle light plant allows an economical operation which uses optimally the electrical power which is available and which secures in all running cycles of the bicycle a lawful, optimal light yield. It can be integrated into already existing bicycle light plants at various design states.

While there are shown and described present preferred embodiments of the invention, it is to be distinctly understood that the invention is not limited thereto, but may be otherwise variously embodied and practiced within the scope of the following claims.

I claim:

1. A light plant for bicycles comprising at least one light bulb, a dynamo driven by the bicycle, at least one switching voltage controller, a rechargeable battery, a charging converter for controlling charging of said battery, and control circuit means operating as a function of dynamo output voltage such that:

at low dynamo output voltage, in a first operation range, said light bulb is driven by said battery and said charging converter is set to use all the power generated by said dynamo for charging said battery,

at medium dynamo output voltage, in a second operation range, said light bulb is driven by said dynamo and said charging converter is set to use a small part of the power generated by said dynamo for charging said battery, and

at high dynamo output voltage, in a third operation range, power corresponding to a nominal operation power of said light bulb is transferred from said dynamo to said light bulb, while said converter is set to use all remaining power of said dynamo for charging said battery.

2. The light plant of claim **1**, wherein said control circuit means sets said charging converter to use all the power generated by said dynamo for charging said battery when said light bulb is switched off.

3. The light plant of claim **1**, comprising a threshold switch for determining said dynamo output voltage and said ranges of operation of the light plant, said threshold switch having a hysteresis such that the transition between said first and second operation range occurs at a higher voltage than the transition between said second and said first operation range.

4. The light plant of claim **1**, wherein said switching voltage controller controls the voltage to said light bulb in said third range of operation.

5. A light plant for bicycles comprising:

at least one light bulb, a dynamo driven by the bicycle, at least two switching voltage controllers, a rechargeable battery, a charging converter for controlling charging of said battery and control circuit means including a threshold switch for monitoring output voltage of said dynamo, such that

depending on the output voltage of said dynamo said charging converter is set to at least a first or a second charging state for adjusting the charging rate of the battery,

depending on the output voltage of said dynamo said light bulb is supplied with voltage either from said dynamo or said battery, and

wherein a first of said switching voltage controllers stabilizes the voltage of said dynamo to a preset higher bulb voltage and a second of said switching voltage controllers stabilizes the voltage of said battery to a preset lower bulb voltage.

6. A light plant for bicycles comprising:

at least one light bulb, a dynamo driven by the bicycle, at least one switching voltage controller, a rechargeable battery, a charging converter for controlling charging of said battery and control circuit means including a threshold switch for monitoring output voltage of said dynamo, such that

depending on the output voltage of said dynamo said charging converter is set to at least a first and a second charging state for adjusting the charging rate of the battery, and

depending on the output voltage of said dynamo, said light bulb is switched off after the output voltage of said dynamo falls below a predetermined minimum voltage.

7. The light plant of claim **6**, wherein said control circuit means comprises a timer circuit to switch off said light bulb after the output voltage of said dynamo is below said predetermined minimum voltage for a predetermined time interval.

* * * * *

United States Patent [19]

Gohda

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[45] **Date of Patent: Sep. 2, 1986**

[54] **POWER ON-OFF CONTROL CIRCUIT**

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[21] Appl. No.: **655,640**

[22] Filed: **Sep. 28, 1984**

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[52] **U.S. Cl.** **363/89**; 363/53; 323/303

[58] **Field of Search** 363/86, 89, 52, 53; 323/266, 276, 303; 361/90, 92

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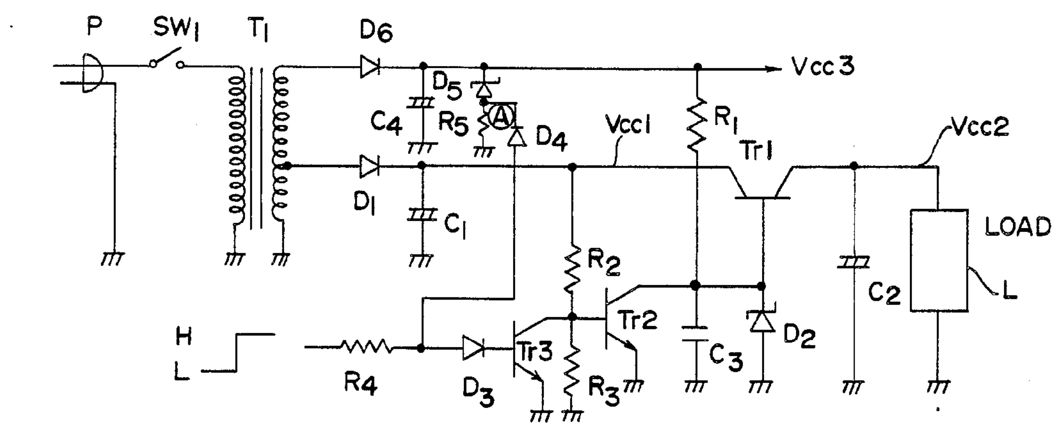
[57] **ABSTRACT**

A power ON-OFF control circuit comprises a power stabilizing circuit for stabilizing power applied from a power source, a supply circuit for supplying a control signal, a detecting circuit for detecting whether the power from the power source is inputted, a switching circuit for disabling the control signal in response to the output of the detecting circuit and a control circuit for controlling ON-OFF states of the power source in response to the switching circuit, the control circuit being connected to the power stabilizing circuit.

6 Claims, 3 Drawing Figures



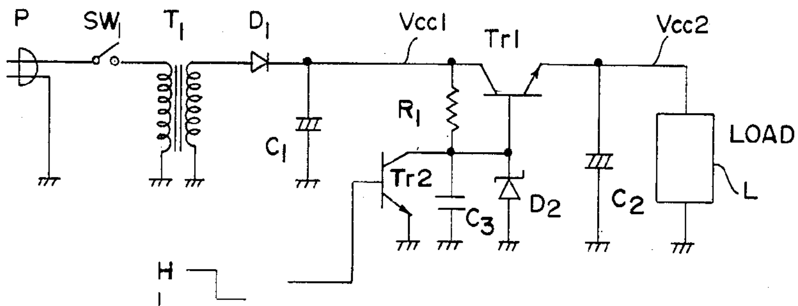


Fig. 1
PRIOR ART

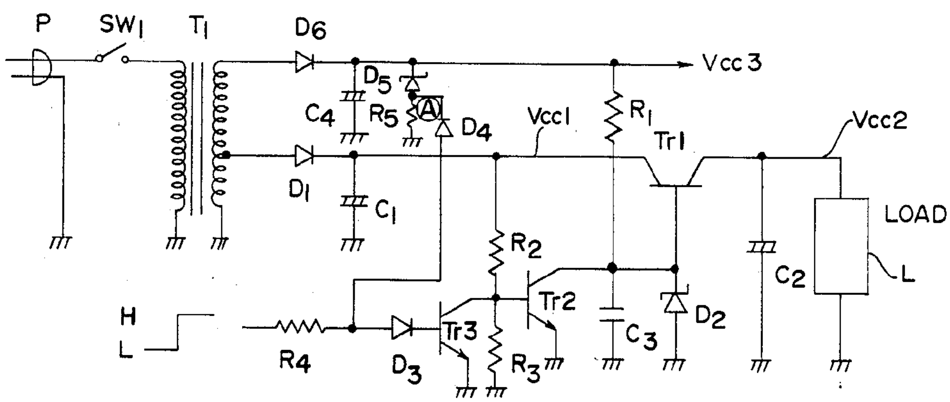


Fig. 2

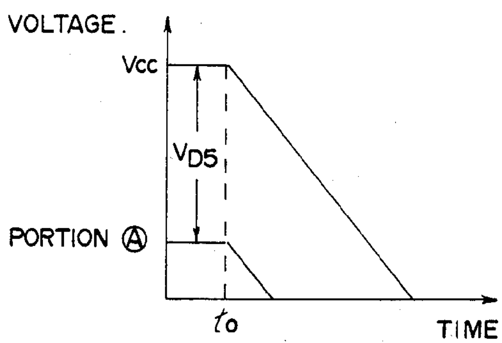


Fig. 3

POWER ON-OFF CONTROL CIRCUIT

BACKGROUND OF THE INVENTION

The present invention relates to a power ON-OFF control circuit and, more particularly, to a power the ON-OFF control circuit for controlling ON-OFF states of a power source such as a relatively small capacity power source which drives an electronic apparatus including a memory.

A power ON-OFF control circuit as shown in FIG. 1 is generally used for controlling the ON-OFF states of a power source. The power ON-OFF control circuit of FIG. 1 includes a power transformer T1, a rectifying diode D1, smoothing condensors C1 and C2, a current control transistor Tr1, a Zener diode D2, a resistance R1, a condensor C3, and a switching transistor Tr2.

A power stabilizing circuit in series comprises the power transformer T1, the rectifying diode D1, the smoothing condensors C1 and C2, the current control transistor Tr1, the Zener diode D2, the resistance R1, and the condensor C3 all operated to stabilize the power from the power source. The switching transistor Tr2 is inserted and connected between the base of the current control transistor Tr1 and the ground, and the switching transistor Tr2 operates to control the ON-OFF states of the power source based on the operation of the above-described power stabilizing circuit.

The power ON-OFF control circuit is connected to an AC (Alternating Current) power source through an AC plug P, and further, connected to a load L to which the power is applied from the AC power source. The power from the AC power source is switched on or off by a main power switch SW1.

The operation of the power ON-OFF control circuit of FIG. 1 will be described below.

When the main power switch SW1 is switched on, an "L" (Low) level control signal is applied to the base of the switching transistor Tr2, so that the switching transistor Tr2 is placed in the OFF state and the current control transistor Tr1 is placed in the ON state. Therefore, a rectifying output voltage Vcc1 at the collector of the current control transistor Tr1 is stabilized by the current control transistor Tr1 and transformed into a DC (Direct Current) voltage Vcc2, and the stabilized DC voltage Vcc2 is further applied to the load L.

When the main power switch SW1 is switched off, a "H" (High) level control signal is applied to the base of the switching transistor Tr2, so that the switching transistor Tr2 is placed in the ON state and the current control transistor Tr1 is placed in the cut-off state. Therefore, the rectifying output voltage Vcc1 is cut off by the current control transistor Tr1 and the DC voltage Vcc2 is not applied to the load L.

However, in the case where the AC plug P is pulled out or the main power switch SW1 is switched off while the "L" level control signal is applied to the base of the switching transistor Tr2, in other words, while the main power switch SW1 is switched on, the DC voltage Vcc2 applied to the load L is gradually decreased as being dependent on the decrease of the rectifying output voltage Vcc1 while the current control transistor Tr1 is continuously placed in the ON state. Because the rectifying output voltage Vcc1 is decreased with small vibration, the DC voltage Vcc2 is gradually decreased with small vibration, also.

If the load L includes a memory such as a semiconductor memory, the memory may be caused to malfunction by the vibration of the DC voltage Vcc2, or the memory contents of the memory may be destroyed.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an improved power ON-OFF control circuit for controlling the ON-OFF states of a power source which drives an electronic apparatus including a memory.

It is another object of the present invention to provide an improved power ON-OFF control circuit for a relatively small capacity power source.

It is a further object of the present invention to provide an improved power ON-OFF control circuit for protecting the memory contents of a memory that is included in an electronic apparatus from being destroyed by a voltage change when a power source is turned ON or OFF.

Other objects and further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. It should be understood, however, that the detailed description of and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

According to an embodiment of the present invention, a power ON-OFF control circuit comprises stabilizing means for stabilizing power applied from a power source, supply means for supplying a control signal, detecting means for detecting whether the power from the power source is inputted, switching means for disabling the control signal in response to the output of the detecting means, and control means for controlling ON-OFF states of the power source in response to the switching means, the control means being connected to the power stabilizing means.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood from the detailed descriptiongiven hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention and wherein:

FIG. 1 shows a circuit diagram of the power ON-OFF control circuit which is used generally;

FIG. 2 shows a circuit diagram of a power ON-OFF control circuit according to an embodiment of the present invention; and

FIG. 3 shows a graph of a transient voltage characteristic for explaining the operation of the power ON-OFF control circuit of FIG. 2.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 2 shows a circuit diagram of a power ON-OFF control circuit according to an embodiment of the present invention. Like elements corresponding to the parts of FIG. 1 are denoted by like reference characters in FIG. 2.

A power ON-OFF control circuit of the present invention comprises a power transformer Tr1, rectifying diodes D1 and D6, smoothing condensors C1, C2, and C4, Zener diodes D2 and D5, a current control transistor Tr1, switching transistors Tr2 and Tr3, resis-

tances R'1, R2, R3, R4, and R5, a diode D3, and a switching diode D4.

The power ON-OFF control circuit is connected to a power source through a plug P and a main power switch SW1, and power from the power source is applied to a load L thorugh the power ON-OFF control circuit.

In the above power ON-OFF control circuit, one end of the resistance R'1 is connected to the base of the current control transistor Tr1, and the other end of the resistance R'1 is connected to an output terminal outputting a rectifying output voltage Vcc3 (Vcc3>Vcc1).

The rectifying diodes D1 and D6 are connected to the power transformer T1 so as to output from the rectifying diode D1 a voltage (Vcc1) less than a voltage (Vcc3) from the rectifying diode D6.

The base of the switching transistor Tr2 is connected to the collector of the current control transistor Tr1 through the resistance R2, and is grounded through the resistance R3. The reverse switching transistor Tr3 is inserted and connected between the base of the switching transistor Tr2 and the ground, and further, the "H" (High) level or "L" (Low) level control signal is applied to the base of the reverse switching transistor Tr3 through the resistance R4 and the diode D3. The connection between the resistance R4 and the diode D3 is connected to the portion Ⓐ between the Zener diode D5 and the resistance R5 through the switching diode D4. The rectifying diode D6 and the smoothing condensor C4 are provided for outputting the relatively high DC voltage Vcc3.

The operation of the above power ON-OFF control circuit of the present invention will be described below.

When the "H" level control signal is applied to the base of the reverse switching transistor Tr3 through the resistance R4 and the diode D3 in the condition that the main power switch SW1 is switched ON and is continuously placed in the ON state, the reverse switching transistor Tr3 is placed in the ON state and the electric potential of the base of the swtiching transistor Tr2 is decreased, so that the transistor Tr2 is placed in the cut-off state. The current control transistor Tr1 is placed in the ON state acording to the cut-off state of the switching transistor Tr2. Accordingly, the stabilized DC voltage Vcc2 is produced and introduced into the emitter of the current control transistor Tr1, and the stabilized DC voltage Vcc2 is applied to the load L.

On the contrary, when the "L" level control signal is applied to an anode of the diode D3 through the resistance R4, the diode D3 and the reverse switching transistor Tr3 are placed in the cut-off state. When the diode D3 and the reverse switching transistor Tr3 are placed in the cut-off state, a voltage at the base of the switching transistor Tr2 is increased, so that the switching transistor Tr2 is placed in the ON state. Therefore, the electric potential at the base of the current control transistor Tr1 is decreased, and the current control transistor Tr1 is placed in the cut-off state. Finally, the supply of the power voltage to the load L is stopped.

In this embodiment, the current control transistor Tr1 is placed in the ON or OFF state according to the "H" or "L" level control signal, respectively, so that the supply of the power voltage to the load L is controlled.

In the condition that the "H" level control signal is applied to the base of the switching transistor Tr3 through the resistance R4 and the diode D3, in other words, that the main power switch SW1 is switched on, the operation of the power ON-OFF control circuit when plug P is pulled out or the main power switch SW1 is switched off will be described below.

In case that the main power switch SW1 is switched off at a time t0, the rectifying output voltages Vcc1 and Vcc3 are decreased under predetermined time constants, respectively. In this time, the electric potential at the connection portion Ⓐ between the Zener diode D5 and the resistance R5 is decreased in proportion to the output voltage Vcc3 as shown in FIG. 3. At the same time, the switching diode D4 is placed in the ON state, and the diode D3 and the reverse switching transistor Tr3 are placed in the OFF state. Accordingly, the switching transistor Tr2 is quickly placed in the ON state, and the current control transistor Tr1 is placed in the cut-off state before the rectifying voltage Vcc1 is decreased less than the DC voltage Vcc2 which is applied to the load L.

As described above, in the above power ON-OFF control circuit, the switching transistors Tr2 and Tr3 are inserted and connected to the base circuit of the current control transistor Tr1 for the power stabilizing circuit in series, and the current control circuit Tr1 is turned ON or OFF by supplying the "H" or "L" level control signal, respectively, to the base of the switching transistor Tr3, so that the supply of the power voltage Vcc2 to the load L is controlled to be stopped or continued. Further, the Zener diode D5 and the resistance R5 are operated to detect whether the power voltages Vcc1 and Vcc2 are inputted. If the voltages Vcc2 and Vcc3 are not inputted, by switching ON the switching diode D4, the transistor Tr3 is placed in the OFF state and the transistor Tr2 is placed in the ON state, so that the current control transistor Tr1 is quickly placed in the OFF state. Therefore, the supply voltage Vcc2, without the vibration is applied to load L even when the power voltage Vcc1 is decreased with the vibration. If the power ON-OFF control circuit of the present invention is applied to the load L such as an electronic apparatus included a memory, memory contents of the memory is protected from being destroyed by a voltage change when the power is turned on or off, and the memory may function correctly.

The power ON-OFF control circuit of the present invention may be applied to television receiver, or the like.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications are intended to be included within the scope of the following claims.

What is claimed is:

1. A power ON/OFF control circuit comprising:

power supply means for providing an input voltage to an electronic apparatus;

dividing means for producing two output voltages from said input voltage wherein one of said output voltages is a reference voltage and a second of said output voltages is a driving voltage;

detection means for detecting the presence or absence of said reference voltage;

stabilizing means for stabilizing said driving voltage and applying said stabilized driving voltage to a load;

control means, operatively connected to said detecting means, for producing control signals in re-

sponse to the presence or absence of an input voltage or the detection of said reference voltage by said detecting means; and

switching means for turning said stabilizing means ON and OFF wherein said switching means is operatively connected to said control means and will turn OFF said stabilizing means when said control signals indicate an absence of said reference voltage or an absence of said input voltage.

2. The circuit of claim **1**, wherein the stabilizing means includes a transistor.

3. The circuit of claim **1**, wherein the control means includes a switching transistor.

4. The circuit of claim **1**, wherein the detecting means includes a Zener diode and a resistance.

5. The circuit of claim **1**, wherein the switching means includes a switching diode.

6. The circuit of claim **2**, wherein the transistor is quickly placed in the cut-off state when the input voltage is interrupted.

* * * * *

EUROPEAN PATENT OFFICE

Patent Abstracts of Japan

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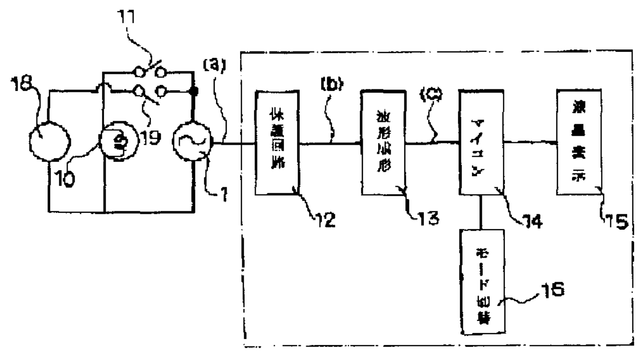
APPLICANT : SANYO ELECTRIC CO LTD;

INVENTOR : TOMITA TATSUHIKO;

INT.CL. : G01P 1/08 B62J 39/00

TITLE : BICYCLE SPEEDOMETER



ABSTRACT : PURPOSE: To provide a speedometer for bicycles which can correctly measure a running speed without requiring any special sensor.

CONSTITUTION: In the speedometer for bicycles which is constituted so as to digitally display a running speed of a bicycle, a waveform of an alternating current output from a hub dynamo 1 for lighting a lamp 10 fixed to the bicycle is converted into a pulse wave by a protecting circuit 12 and a waveform- forming circuit 13. A running speed of the bicycle is measured by a microcomputer 14 based on an interval of the pulse waves and a peripheral length of a wheel stored in an internal RAM beforehand.

6

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審査請求　未請求　請求項の数１　ＯＬ　（全５頁）

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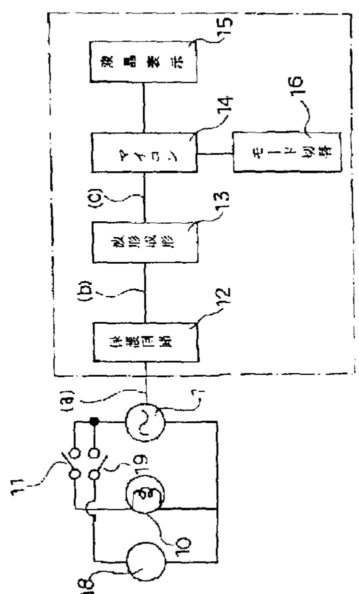
(54)【発明の名称】　自転車のスピードメーター

(57)【要約】

【目的】　特別なセンサーを必要とせず、且つ正確に走行速度の計測が行える自転車のスピードメーターを提供することを目的とする。

【構成】　自転車の走行速度をディジタル表示するように構成された自転車のスピードメーターにおいて、自転車に取り付けられるランプ１０点灯用のハブダイナモ１から出力される交流電流の交流波形を、保護回路１２及び波形成形回路１３によってパルス波に変換し、このパルス波のパルス間隔と予め内部ＲＡＭに格納してある車輪周長とに基づいてマイクロコンピューター１４によって自転車の走行速度を計測するように構成した。



【特許請求の範囲】

【請求項1】 自転車の走行速度をディジタル表示するように構成された自転車のスピードメーターにおいて、自転車に取り付けられる発電機から出力される交流電流の交流波形に基づいてその周波数に応じたパルス波を生成する手段と、上記パルス波に基づいて走行速度を演算する手段とを備えたことを特徴とする自転車のスピードメーター。

【発明の詳細な説明】

【0001】

【産業上の利用分野】本発明は、自転車のスピードメーターに関する。

【0002】

【従来の技術】従来の自転車のスピードメーターでは、走行速度算出に必要となる車輪の回転に対応した信号を磁気センサー等によって検出している。図8は、従来の自転車のスピードメーターにおけるセンサー部を示した図である。車輪５０のスポーク５１にはビス等によりマグネット５２を取り付け、自転車のフォーク５３にはリードスイッチ５４を取り付けている。車輪５０が一回転するごとに、マグネット５２がリードスイッチ５４の前を横切り、このときにリードスイッチ５４がＯＮ／ＯＦＦし、このＯＮ／ＯＦＦ信号が図示しない波形成形部により成形されてマイクロコンピューターに入力される。マイクロコンピューターは、内部発振器からの駆動クロックに基づいて上記のＯＮ／ＯＦＦ信号から自転車の走行速度を算出し、これを表示部にディジタル表示させる。

【0003】

【発明が解決しようとする課題】しかしながら、上記従来の自転車のスピードメーターでは、マグネット５２の取り付けが正確に行われていない場合には感度不良を生じ、リードスイッチ５４のＯＮ／ＯＦＦが確実に行われないことがある。特に、走行時の振動や転倒時の衝撃などでマグネット５２の取り付け位置がずれやすいために、感度不良もそれだけ生じやすいという欠点がある。

【0004】また、車輪５０が一回転する間に一回のスイッチ動作しか行われないため、低速走行時には、マイクロコンピューターにおける検出タイミングとの関係で、走行速度の演算結果に誤差が生じやすいという欠点も有している。

【0005】本発明は、上記の事情に鑑み、特別なセンサーを必要とせず、且つ正確に走行速度の計測が行える自転車のスピードメーターを提供することを目的とする。

【0006】

【課題を解決するための手段】本発明の自転車のスピードメーターは、上記の課題を解決するために、自転車の走行速度をディジタル表示するように構成された自転車のスピードメーターにおいて、自転車に取り付けられる発電機から出力される交流電流の交流波形に基づいてその周波数に応じたパルス波を生成する手段と、上記パルス波に基づいて走行速度を演算する手段とを備えたことを特徴とする。

【0007】

【作用】発電機から出力される交流電流の交流波形は、車輪の回転速度によって変化するので、この交流波形の変化（周波数変化）に基づくパルス波の変化から自転車の走行速度を計測することが可能である。そして、発電機は、一般には自転車に既設されているものであるから、従来のごとく、マグネットとリードスイッチから成るセンサーを別に必要としない分、価格が割安になる。更に、発電機から出力される交流電流の交流波形は、通常は車輪の一回転で１Ｈｚより高い周波数が得られるので、車輪が一回転する間に一回のスイッチ動作しか行われない従来の自転車のスピードメーターに比べ、低速時の走行速度の計測が正確に行えることになる。

【0008】なお、発電機の電圧値に基づいて速度計測を行うとした場合、自転車の走行速度をディジタル表示するためには、上記電圧値をディジタル化するＡ／Ｄ変換回路が必要となり、価格が割高になる。本発明では、Ａ／Ｄ変換器は必要としないため、低価格が実現できる。

【0009】

【実施例】以下、本発明をその実施例を示す図に基づいて説明する。

【0010】図１（ａ）は、自転車に取り付けられるランプ用発電機としてのハブダイナモ１を示した断面図、同図（ｂ）はハブダイナモを構成しているローター２及びステータ３を示す断面図、同図（ｃ）は同じくローター２及びステータ３を示す正面図である。

【0011】ハブ軸（車軸）４は自転車のフォーク５に固定状態に取り付けられており、このハブ軸４に前記のステータ３を固着してある。ステータ３は、ステータコア３ａの内部に発電コイル３ｂを嵌装して成るものである。一方、ハブ体６は、一対のベアリング７，８を介して前記ハブ軸４に対して回転自在に設けられたものであり、車輪とともに回転する。ハブ体６には、前記のステータ３の配置に対応して大径部６ａが形成されており、この大径部６ａに前記のローター２が固設されている。このローター２は、上記の大径部６ａの内周面に配備された環状のヨーク２ａと、このヨーク２ａの内周面に接着剤などで固着された４つのマグネット２ｂ…とから成る。各マグネット２ｂはＮ極とＳ極とを交互に合計で８極有し、４つのマグネット２ｂ…全体では３２極が形成される。従って、車輪が１秒間に１回転すれば１６Ｈｚの交流電流が得られるようになっている。なお、本実施例では、６Ｖ－２．４Ｗ仕様のものを用いている。

【0012】図２は、ハブダイナモ１を電源として点灯されるランプ１０、このランプ１０の点灯をＯＮ／ＯＦ

Fするスイッチ１１、ハブダイナモ１を電源として駆動される警報ブザー装置１８、この警報ブザー装置１８の駆動をＯＮ／ＯＦＦするスイッチ１９、及びハブダイナモ１をセンサーとして走行速度を演算するように構成された自転車のスピードメーター１７の回路構成を示したブロック図である。

【００１３】ハブダイナモ1からは、図３の（ａ）に示すように、走行速度によって周波数の異なる交流電流が出力される。そして、この出力が保護回路１２に通されることにより、同図の（ｂ）に示すように、半波整流および電圧レベル規制がなされた信号が得られる。更に、この信号が波形成形回路１２に入力されることにより、同図（ｃ）に示すように、交流電流の周波数に対応したパルス波が生成され、マイクロコンピューター１４に入力される。

【００１４】マイクロコンピューター１４は、上記のパルス波の周期（パルス間隔）と予め内部ＲＡＭに記憶させている車輪周長とに基づいて走行速度計算を行う。マイクロコンピューター１７により計算された走行速度は、上記の液晶表示部１５上にｋｍ／ｈ単位或いはｍｉｌｅ／ｈ単位でディジタル表示される。

【００１５】図４の（ａ）は、自転車のスピードメーター１７の外観を示す平面図であり、同図の（ｂ）はスピードメーター１７が取付台座２０に装着されている状態での断面図である。スピードメーター１７の外観表面には、前述の液晶表示部１５、及びモード切り替え部１６におけるモードキー１６ａやＳＴ／ＳＴＯＰキー１６ｂが配置されている。なお、モードキー１６ａのキー操作により、現在時刻、走行距離、走行積算距離等に表示を切り替え得るようになっている。

【００１６】以上のように、上記の自転車のスピードメーター１７は、ランプ用等として一般に既設されているハブダイナモ１を速度センサーとして用いものであり、従来のごとく、マグネットとリードスイッチから成るセンサーを別に必要としない分、価格が割安になる。更に、ハブダイナモ１には磁極が３２極設けられており、車輪が１秒間に１回転すれば１６Ｈｚの交流電流（パルス）が得られることになるので、車輪が一回転する間に一回のスイッチ動作しか行われない従来の自転車のスピードメーターに比べ、低速時の速度計測が正確に行えることになる。

【００１７】次に、警報ブザー装置１８について説明する。図５は警報ブザー装置１８の設置位置を示した自転車前部の外観図であり、図６の（ａ）は警報ブザー装置１８の側面断面図、同図の（ｂ）は平面図である。これらの図に示されるように、警報ブザー装置１８はその側面部に設けられたハンドル取付ベルト１８ａによって自転車のハンドル２１に取り付けられる。

【００１８】また、図６は警報ブザー装置１８の回路構成図である。この警報ブザー装置１８は、ハブダイナモ１からの交流電流を直流化するためのダイオード２５…及び平滑コンデンサ２６からなる整流部、抵抗２７とツェナーダイオード２８から成る保護回路部、及び、ブザー（電磁ブザー或いは圧電ブザーなどが用いられる）２９から成る。

【００１９】上記の警報ブザー装置１８では、その駆動電力をハブダイナモ１から得るようにしているので、ブザー用の乾電池は不要になる。通常、警報は走行時において鳴らされるものであるから、走行時にのみ発電するハブダイナモ１を駆動電力源としても特に不都合は生じない。更に、走行時にブザーを鳴らすときには、これと同時にブレーキをかけて減速することが多いが、ブザー駆動時には、ハブダイナモ１にて発生された電力を消費するので、ハブダイナモ１による車輪への制動力が生じることになり、減速が容易に行えるという利点も有する。

【００２０】なお、コンデンサ２６の容量を大きくしてこれを蓄電用に用いることもでき、このようにすれば、停止時においても数十秒程度間はブザーを鳴らすことが可能となる。

【００２１】また、上記のごとくハブダイナモ１からの交流電流を直流化してブザー２９を駆動したが、ハブダイナモ１からの交流電流の周波数を人の可聴域に対応する周波数に高める（例えば、ハブダイナモ１の磁極数をより多くする）ようにすれば、ハブダイナモ１からの交流電流を直接利用して圧電振動子等を駆動して警報音を出力させせることも可能である。

【００２２】また、車輪の側面に回転軸を必要に応じて当接させて発電するブロック型のダイナモを用いてもよいが、走行状態では常に発電することになるハブダイナモ１を用いる方が望ましいといえる。

【００２３】

【発明の効果】以上のように、本発明によれば、発電機（ダイナモ）をセンサーとして用いてその交流波形に基づいて速度計測を行うようにしたので、別にセンサーを設けることが不要になりコストの低減が図れるとともに、低速走行時の速度計測が正確に行えるという効果も併せて奏する。

【図面の簡単な説明】

【図１】同図（ａ）はハブダイナモの断面図、同図（ｂ）はハブダイナモを構成しているローター及びステータを示す断面図、同図（ｃ）はローター及びステータを示す正面図である。

【図２】本発明の自転車のスピードメーターの回路構成を中心に示したブロック図である。

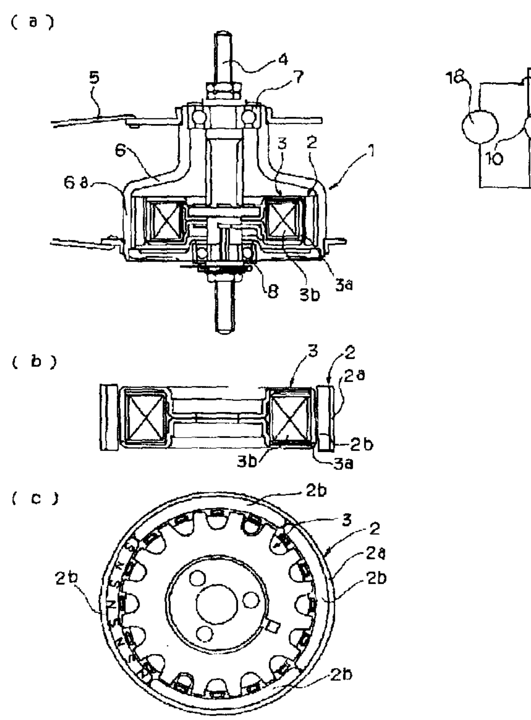
【図３】図２における各部の出力波形を示したグラフである。

【図４】同図（ａ）は、自転車のスピードメーターの外観を示す平面図、同図の（ｂ）はスピードメーターが取付台座に装着されている状態での断面図である。

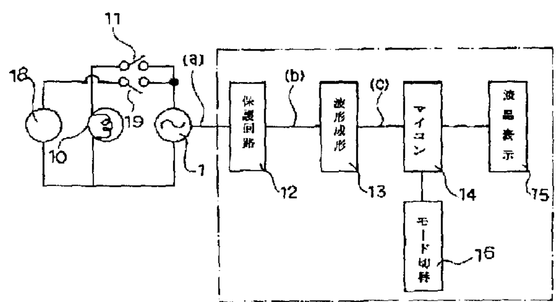
【図5】警報ブザー装置の設置位置を示した自転車前部の外観図である。
【図6】同図の（a）は警報ブザー装置の側面断面図、同図の（b）はその平面図である。
【図7】警報ブザー装置の回路構成を示した回路図である。
【図8】従来の自転車のスピードメーターのセンサー部の取付状態を示した自転車前部の側面図である。
【符号の説明】

1　ハブダイナモ（発電機）
12　保護回路
13　波形成形回路
14　マイクロコンピューター
15　液晶表示部
16　モード切り替え部
17　自転車のスピードメーター
18　警報ブザー装置

【図1】



【図2】



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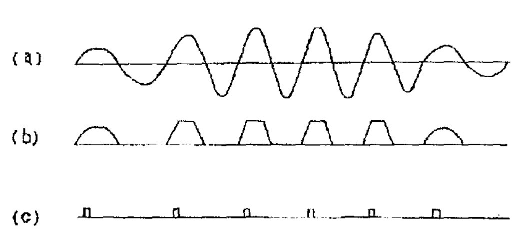

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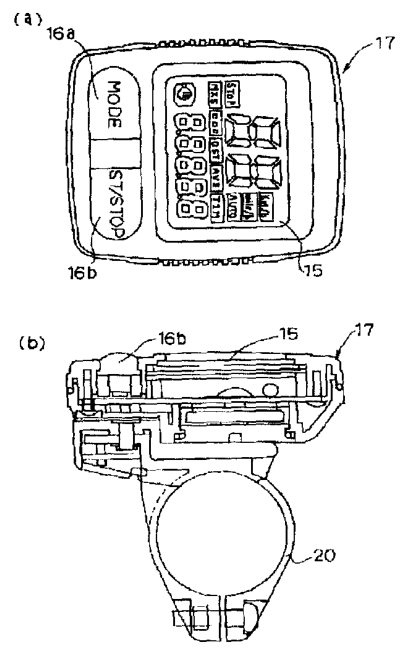

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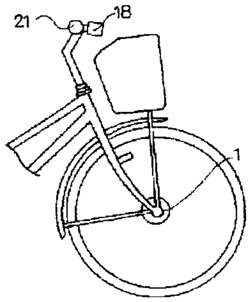
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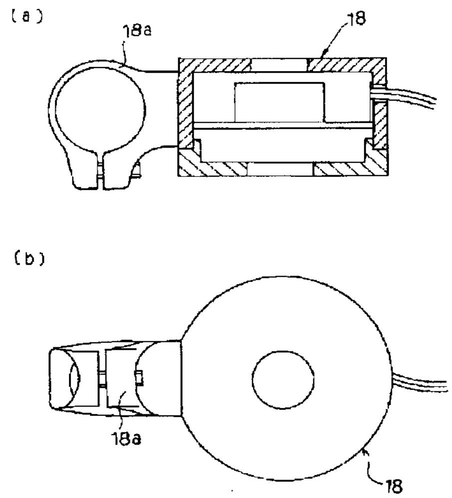
【図6】


(a)
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(b)
18a
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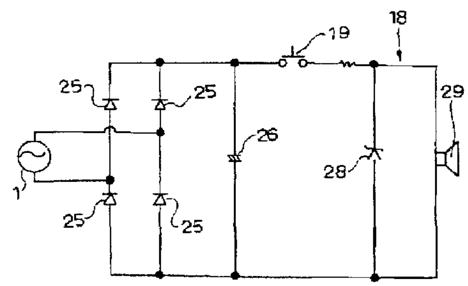
【図7】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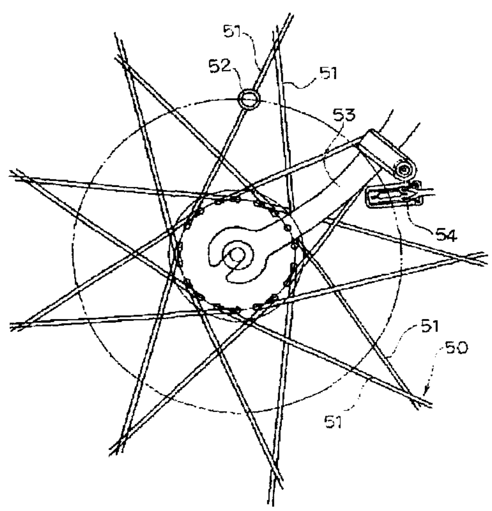
【図8】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(54) **ELECTRIC BICYCLE AND METHODS**

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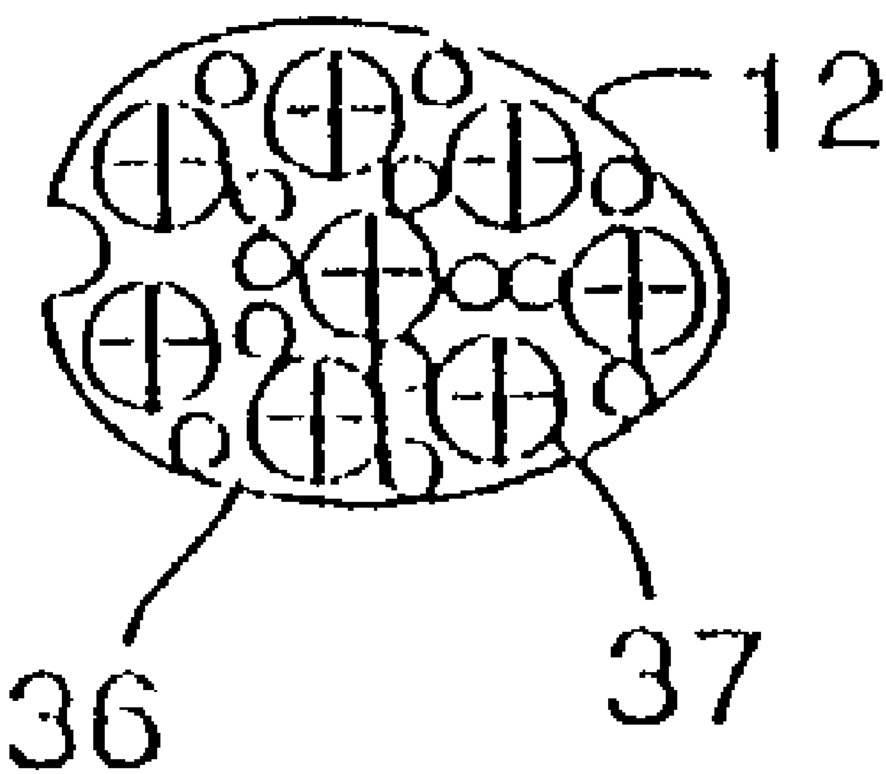
(57) **ABSTRACT**

An electric motor assembly comprises a housing and a spindle disposed to rotate in the housing. A motor is provided which comprises a stator coupled to the housing, and a rotor rotatably disposed within the stator such that the rotor is disposed about the spindle. The assembly further includes an output driver, and a gear system operably coupled to the rotor and the output driver to rotate the output driver upon operation of the motor.



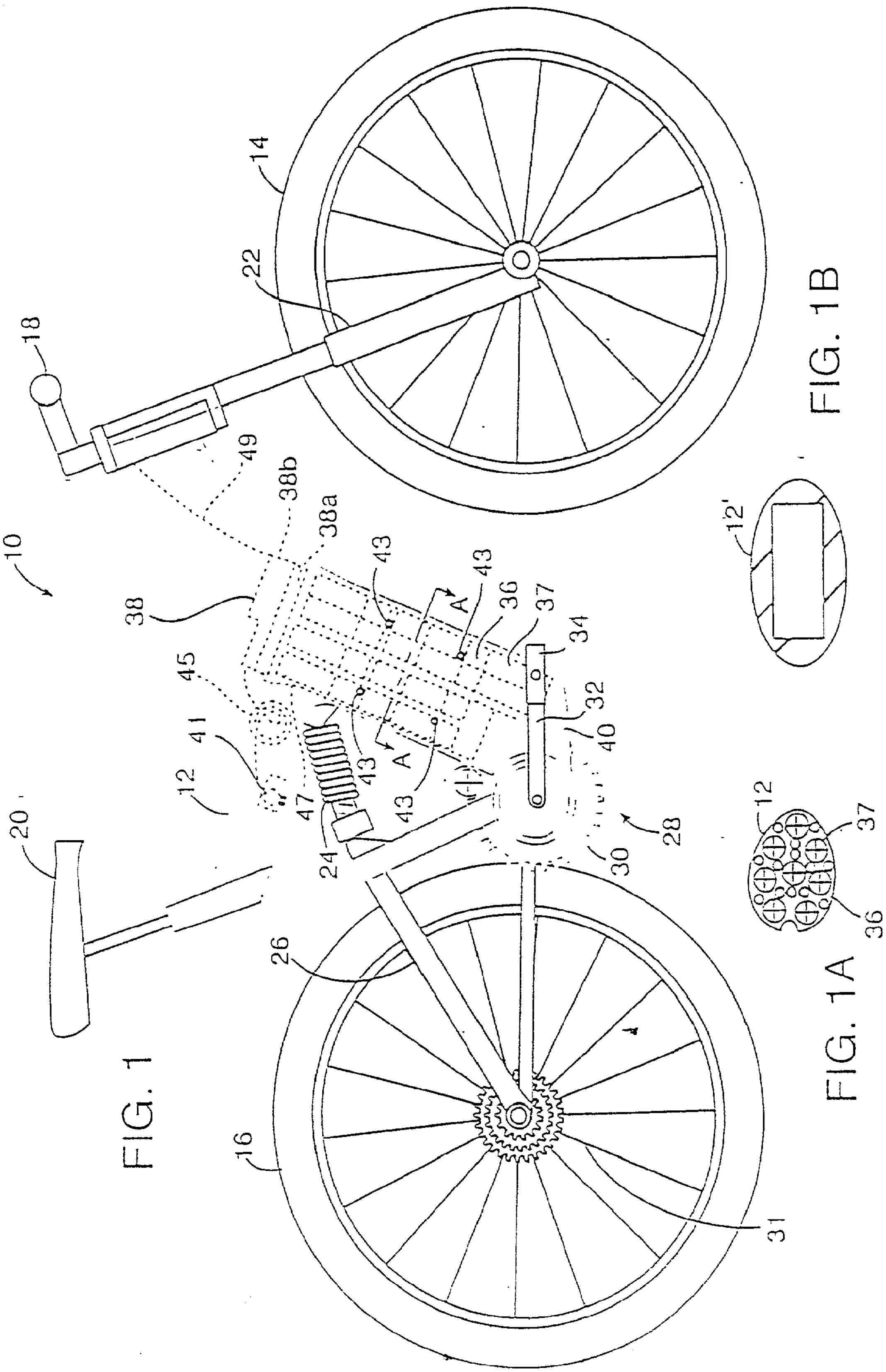


FIG. 1

FIG. 1A

FIG. 1B

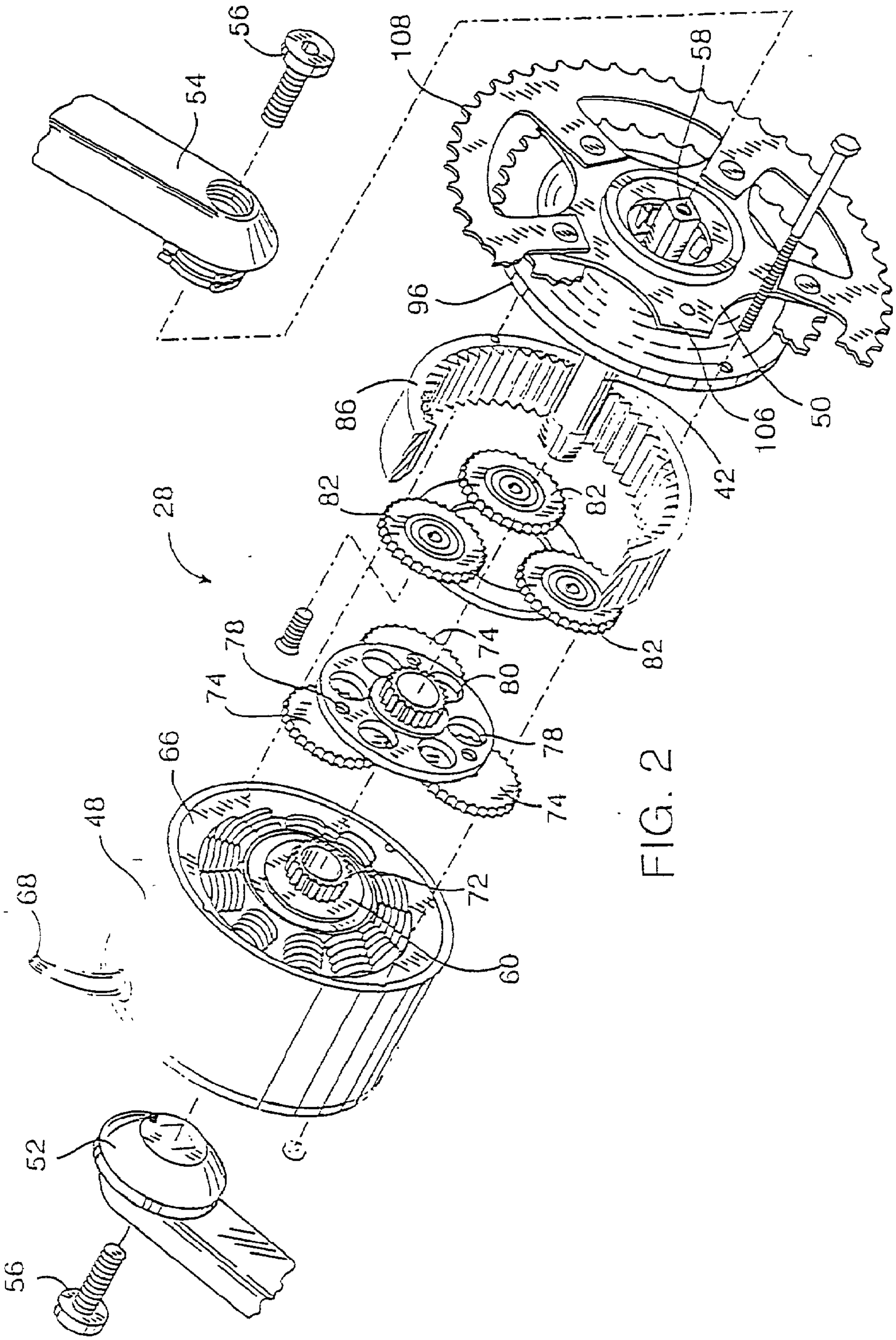

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FIG. 2

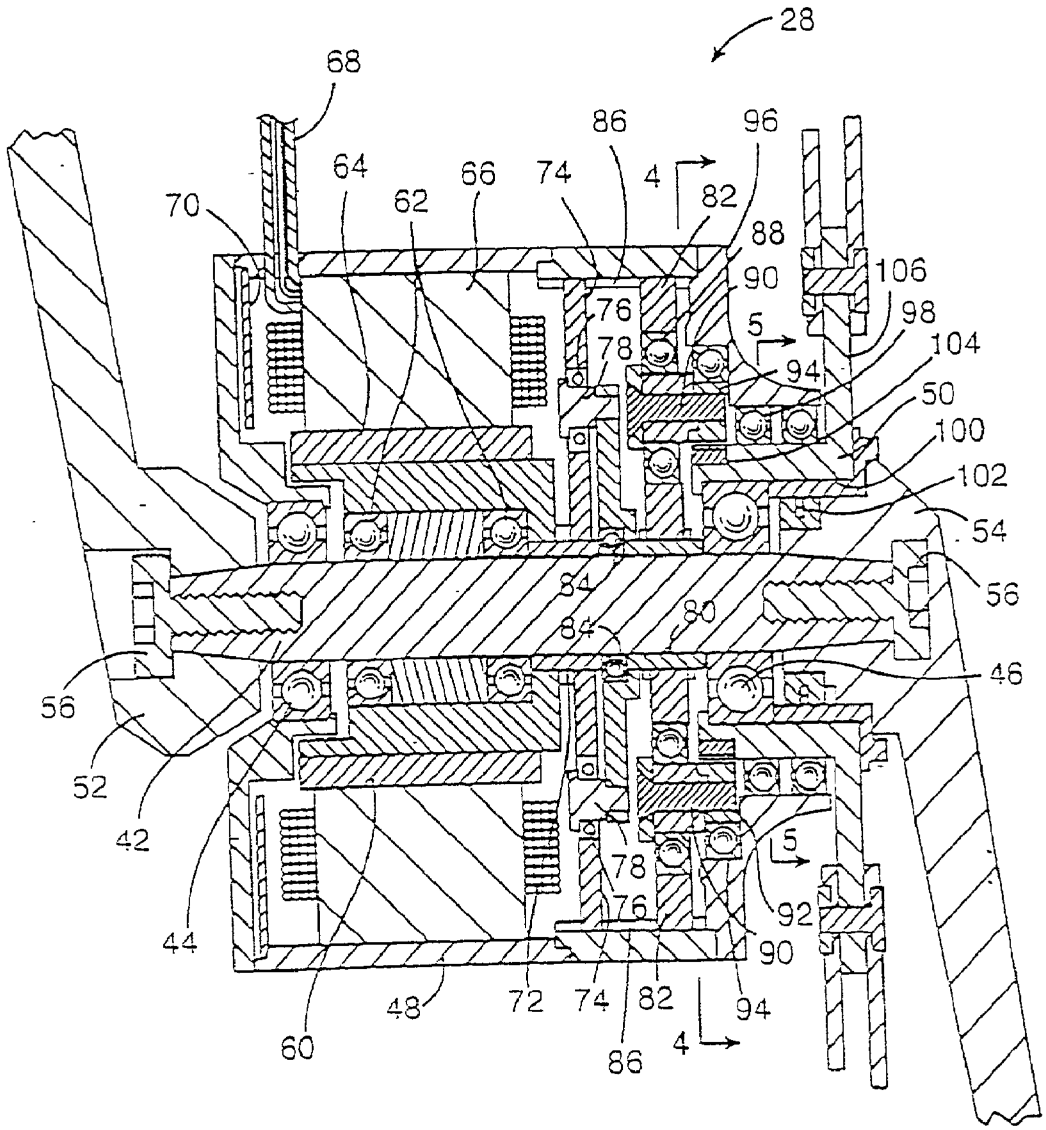
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FIG. 3

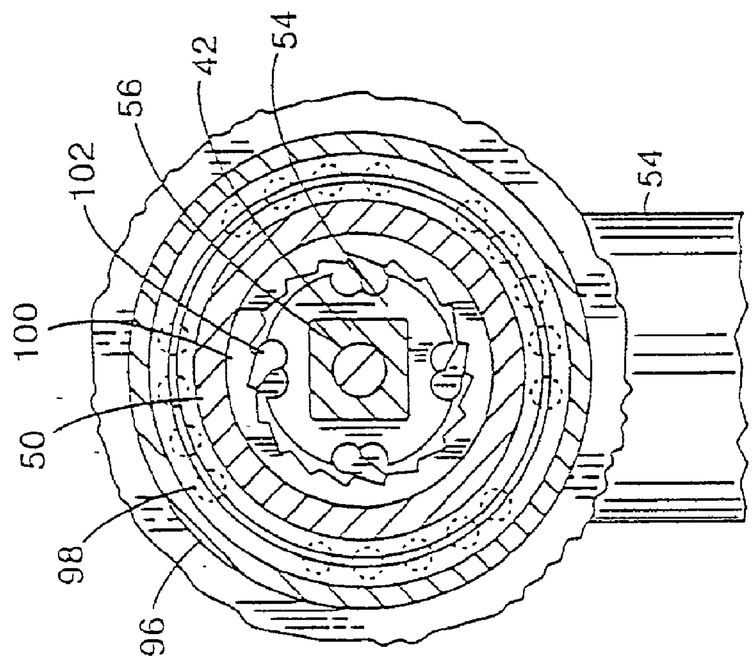

FIG. 5

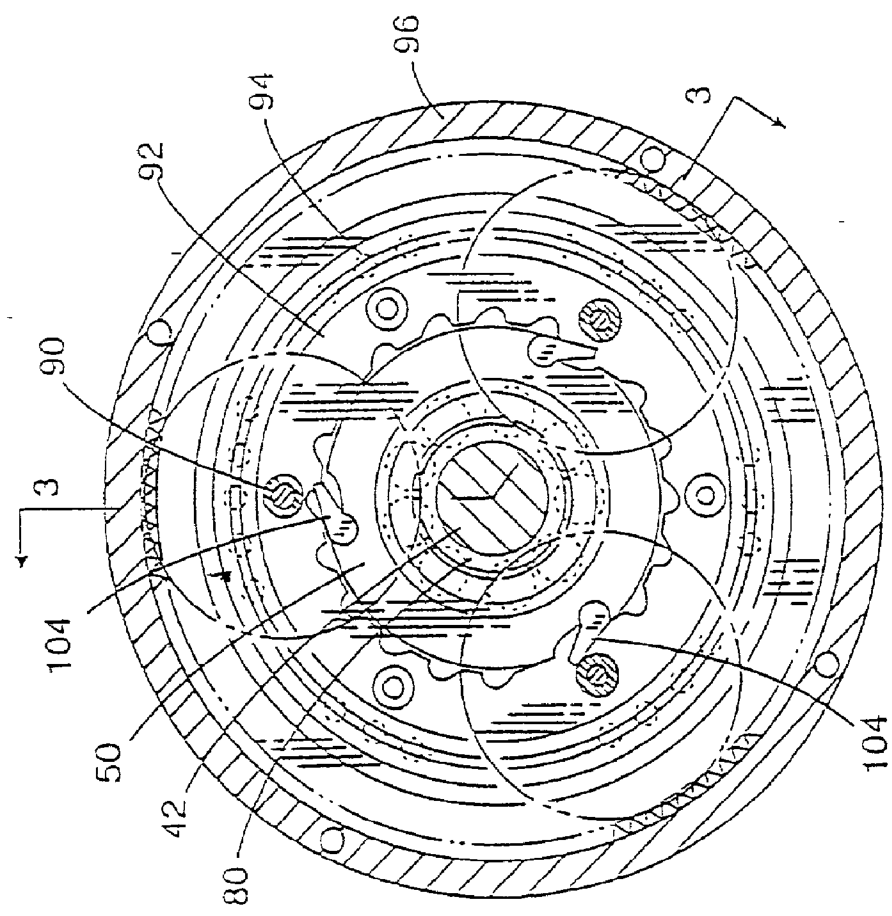

FIG. 4

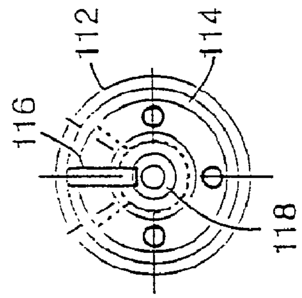

FIG. 6A

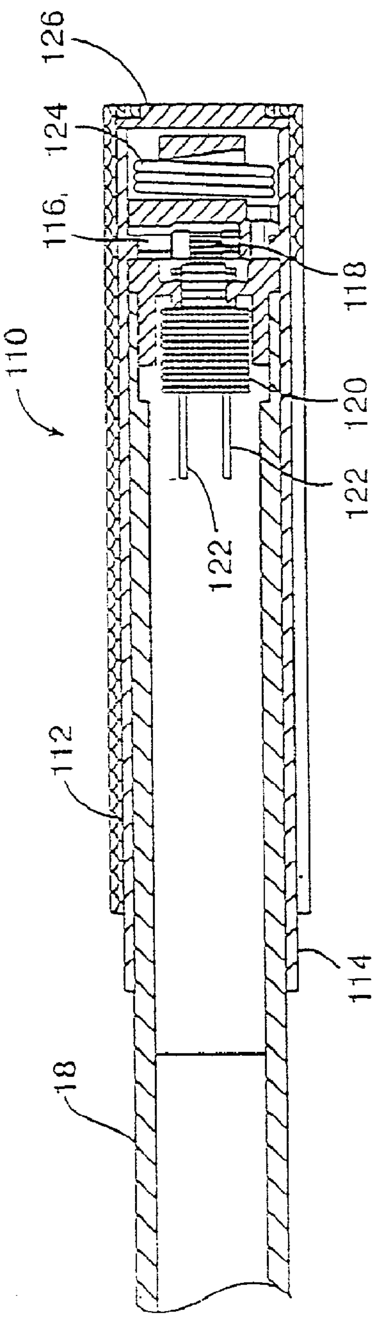

FIG. 6

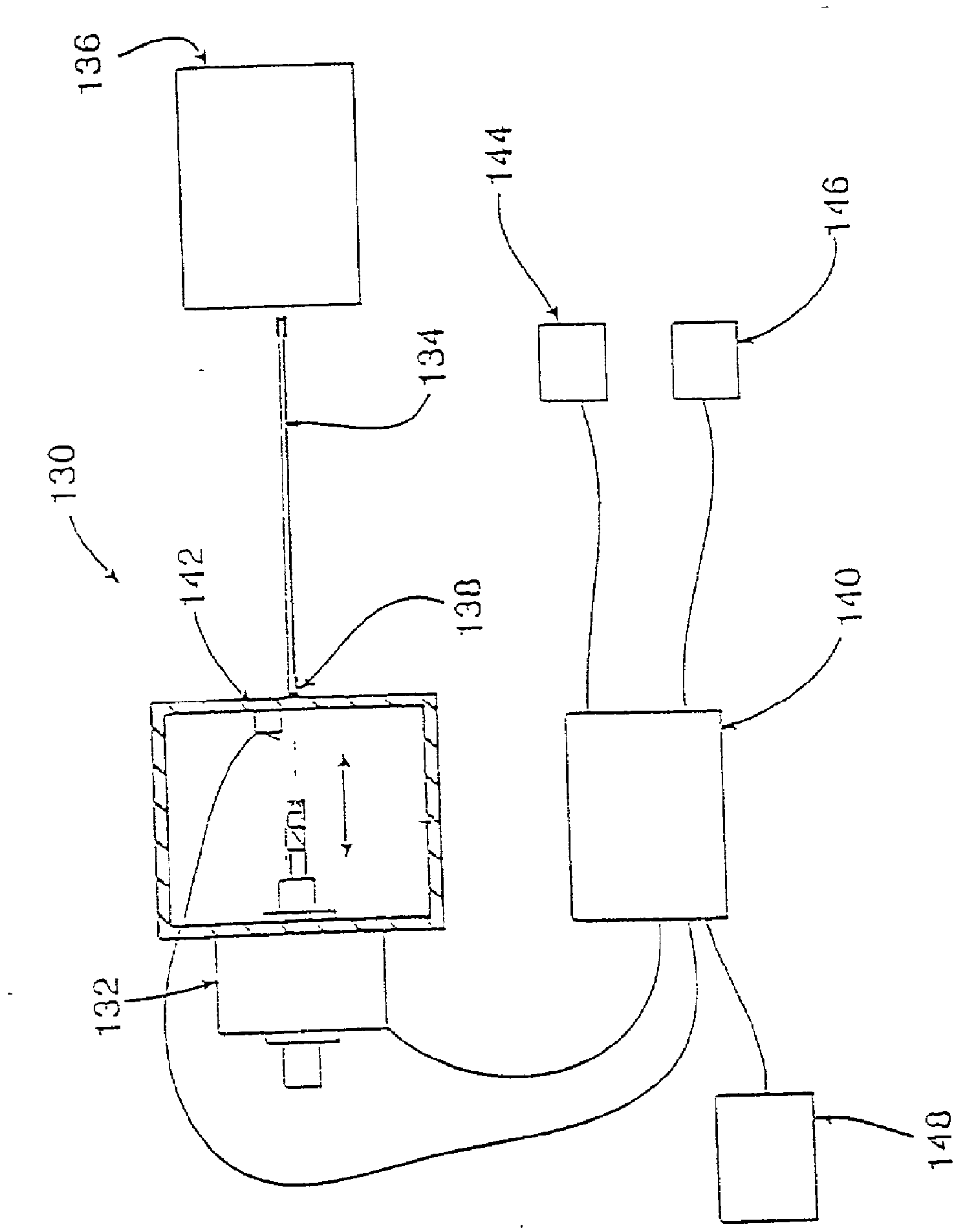

FIG. 7

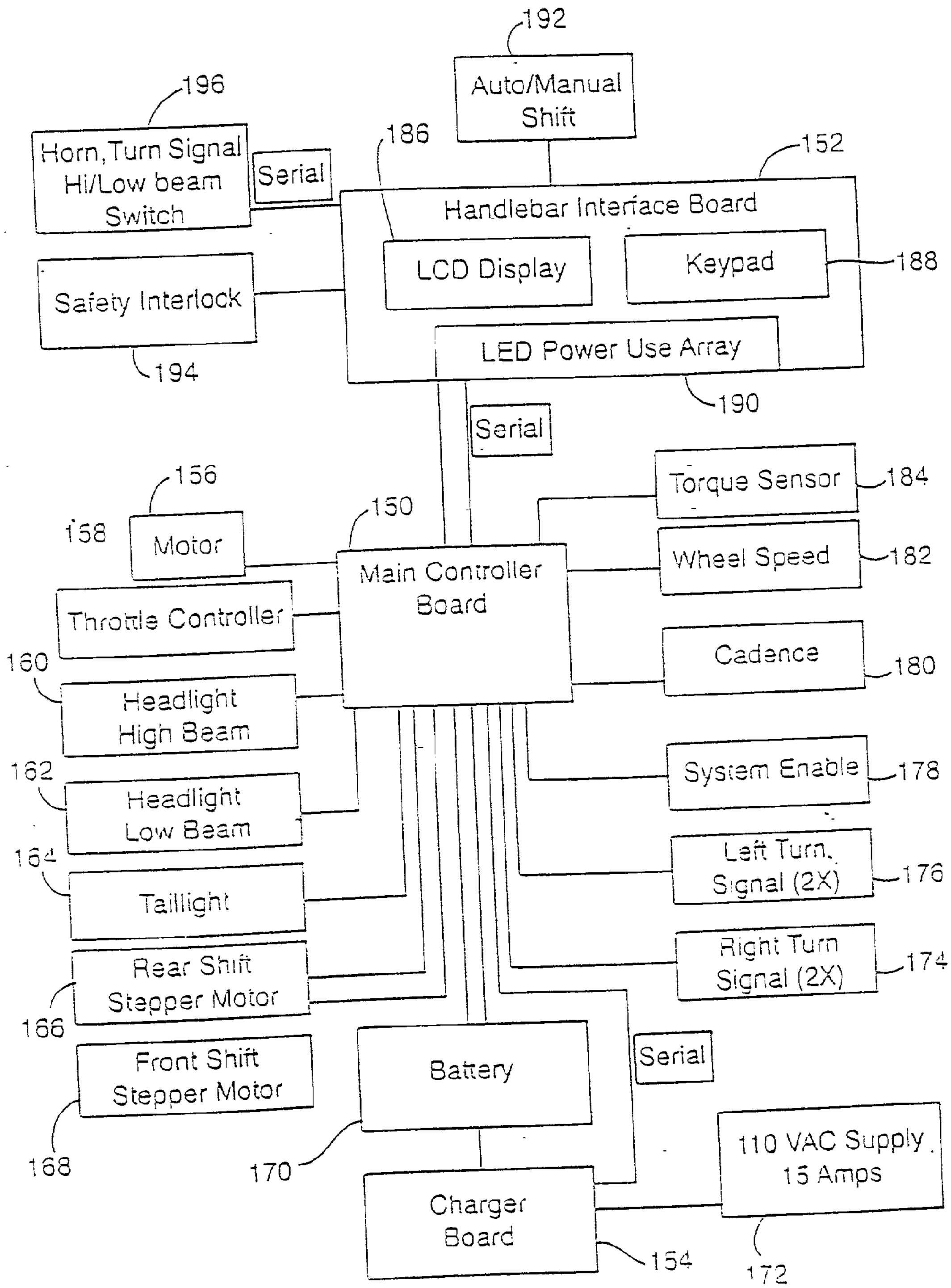
192
Auto/Manual Shift
196
Horn, Turn Signal Hi/Low beam Switch
Serial
186
152
Handlebar Interface Board
LCD Display
Keypad
188
Safety Interlock
194
LED Power Use Array
190
Serial
Torque Sensor
184
156
Motor
158
150
Main Controller Board
Wheel Speed
182
Throttle Controller
160
Headlight High Beam
Cadence
180
162
Headlight Low Beam
System Enable
178
164
Taillight
Left Turn Signal (2X)
176
Rear Shift Stepper Motor
Right Turn Signal (2X)
174
166
Front Shift Stepper Motor
Battery
Serial
168
170
110 VAC Supply 15 Amps
Charger Board
154
172

FIG. 8

ELECTRIC BICYCLE AND METHODS

BACKGROUND OF THE INVENTION

[0001] The invention relates generally to the field of cycles, and in particular to bicycles. More specifically, the invention relates to an electric assist bicycle which is configured to maximize the efficiency of the motor and to prolong the life of the battery which supplies electrical current to the motor.

[0002] Over the last 150 years, the bicycle has evolved to become one of the most efficient means of transportation in terms of conversion of energy into distance traveled. For example, most modern bicycles require only about 400 watts (½ horsepower) to propel the bicycle at 15 m.p.h. on level ground. The efficiency of the bicycle has also been optimized to minimize the effort required by the rider. For instance, most modern bicycles include an efficient gear system to minimize rider effort.

[0003] To further reduce the amount of human effort required to propel a bicycle, a variety of electric bicycles have been introduced. Presently, about 50 to 100 companies are producing or are planning to produce electric bicycles. In most cases, however, such bicycles do not utilize the efficiency of the bicycle through the use of mechanical gears.

[0004] The human muscle and modern battery are similar in their ability to produce power from stored energy. Similarly, both are able to produce more energy by keeping the torque per stroke low and the frequency high.

[0005] The human muscle is able to function in two states: anaerobic or aerobic. In anaerobic contraction, the muscle utilizes stored ATP fuel to power the muscle without the need for oxygen. In this case, the muscle can produce large amounts of energy for a short duration. The byproduct of this high energy output is lactic acid. As muscle contraction continues in an anaerobic state, the lactic acid in the muscle builds until it inhibits further muscle contraction. After a period of rest, the lactic acid is removed from the muscle by the blood system and muscle contraction can continue (assuming a sufficient store of ATP fuel). Aerobic muscle contraction allows for extended periods of exertion, but at a lower level of power than anaerobic exercise. In aerobic exercise, sufficient oxygen is supplied to the muscle so that the muscle is able to use the soluble fat in the blood as the primary fuel.

[0006] The gears of modern bicycle allow the rider to exercise the muscle in the aerobic range to allow continuous long distance riding. The gears are utilized to keep the rider's pedal speed at a high rotating speed (usually between about 60 to 100 rpm). At higher pedaling speeds, the force output for muscle contraction is low so that the muscle is able to stay in the aerobic region.

[0007] The original bicycle used a single fixed gear ratio (similar to most electric bicycles) and was severely limited in its ability to negotiate steep terrain. The number of gears on a bicycle has evolved so that the present mountain bike has up to 27 gears to allow for riding on a variety of terrains.

[0008] Similar to the human muscle, the modern battery has an efficient and an inefficient region. The battery delivers current to the motor, which produces torque in the motor. The motor torque increases linearly with motor current. High currents are inefficient.

[0009] At high current discharge rates, the battery experiences problems similar to lactic acid buildup in the human muscle. More specifically, in the battery, hydrogen gas is formed on the charge plate. Hydrogen gas acts as a barrier to the transfer of electrons. As the high current discharge continues, the hydrogen continues to build on the plates until the battery is unable to deliver current.

[0010] Another important issue to consider at high current discharge rate is that the run time of the battery is reduced exponentially with linear increases in motor current. Further, motor thermal losses are experienced which increase with the square of the motor current. Hence, increased motor current wastes available energy two non-linear ways, i.e., battery losses and motor resistance losses.

[0011] As one example, a motor mounted directly to the rear wheel on the bicycle has only a fixed gear ratio. Hence, to obtain a four times increase in torque, the motor current must be increased by four times. However, the four times increase in the motor current increases motor resistive losses by 16 times and thus results in a significant loss in battery run time and reduction in motor efficiency.

[0012] The available power from the battery is an exponential function of the rate of current use. Hence, as current discharge increases, the available energy from the battery decreases exponentially. Hence, as more torque is required to move the bicycle (such as during hill climbing or acceleration), more current will be required, thereby exponentially decreasing the available power from the battery.

[0013] Hence, it would be desirable to provide improved electrically assisted bicycles and methods for their use which would overcome or greatly reduce these and other problems. The electric bicycles of the invention should be configured to maximize the efficiency of the motor, minimize current use, and thus maximize battery life. It would be desirable if such features could be accomplished by minimizing the required torque while keeping the rotational rate of the motor as high as possible. Preferably, the electric bicycles of the invention will employ the use of a gear system so that torque may be minimized, especially during hill climbing and acceleration. It would further be desirable if the electric bicycles of the invention provided for automatic shifting to keep the motor speed near maximum output while minimizing torque. In another aspect, it would be desirable if such electric bicycles were able to operate using either the motor or the pedals in a parallel manner. At the same time, it would be preferable if such electric bicycles employed the use of a motor which did not turn the crank arms. Such electric bicycles and methods should also be compatible with conventional bicycle equipment, such as derailleurs so that shifting may be accomplished with minimal modification to existing bicycles. Finally, it would be preferable to incorporate the batteries into the bicycle in a manner such that the overall appearance of the bicycle is aesthetically pleasing, such the batteries are protected, and such that the bicycle is provided with a low center of gravity.

SUMMARY OF THE INVENTION

[0014] The invention provides exemplary electric motor assemblies, electrically assisted bicycles, and methods for their use. In one exemplary embodiment, the invention provides an electric motor assembly which comprises a housing and a spindle that is disposed to rotate in the

housing. A motor is disposed within the housing and comprises a stator coupled to the housing and a rotor rotatably disposed within the stator such that the rotor is disposed about the spindle. The motor assembly further includes an output driver, and a gear system operably coupled to the rotor and the output driver to rotate the output driver upon operation of the motor.

[0015] The disposition of the motor and output driver within the housing is advantageous in that it facilitates packaging and manufacturing of the motor assembly. Preferably, the spindle is aligned with a central axis of the housing, with the rotor being concentrically disposed about the spindle, and the stator being concentrically disposed about the rotor. Such a configuration allows for a compact design to allow the motor to conveniently fit within the housing.

[0016] In another particularly preferable aspect, a front sprocket assembly is operably coupled to the output driver such that the sprocket assembly rotates upon rotation of the output driver. By having the motor turn the sprocket assembly, the motor assembly may be used in connection with mechanical gears of the modern bicycle to minimize the amount of torque required, thereby greatly increasing battery life.

[0017] In another particular aspect, the gear system is coupled to a motor driver. The motor assembly further includes a first clutch to engage the motor driver with the output driver when the motor driver is rotated faster than the output driver. In this way, when the rider is pedaling at a rate which causes the output driver to rotate faster than the motor is turning the motor driver, the first clutch will not engage the motor driver with the output driver. Hence, the rider is able to pedal the bicycle and not turn the motor. Conversely, if the motor turns the motor driver at a rate which is faster than the rider is pedalling, the first clutch is engaged so that the motor causes the output driver (and hence the sprockets) to rotate. Optionally, another clutch mechanism may be provided which allows the rider to engage the clutch during pedaling for regenerative charging of the battery.

[0018] In yet another aspect, a crank arm is coupled to the spindle, and a pedal is coupled to a crank arm. A second clutch is also provided to engage the crank arm with the output driver when the crank arm is rotated faster than the output driver (thereby releasing the first clutch) so that the rider's legs cause rotation of the output driver. Use of the second clutch is also advantageous because, when the motor is turning the output driver, the second clutch will ensure that the crank arm is disengaged. In this way, the motor is able to turn the sprocket assembly but not the crank arms. Preferably, the first clutch and the second clutch are coaxially aligned with an axis of the spindle to allow for packaging of the motor in the small space available between the crank arms.

[0019] In yet another aspect, the gear system comprises a set of planetary gears to rotate the output driver at a rate of rotation that is less than the motor. Preferably, the gears are configured so that the output speed of the motor is matched to the range of the human leg. For example, the planetary gears are preferably configured so that when the rate of rotation of the motor is in the rate from about 1,800 rpm to about 3,600 rpm, the rate of rotation of the output driver is in the range from about 60 rpm to about 120 rpm. In a specific aspect, the motor speed is approximately 2400 rpm and is employed to turn the crank arms at a rate of about 75 rpm. Such a gear reduction facilitates use of either the motor or pedal power to drive the bicycle. The motor is preferably operated at or near its maximum output level to maximize the efficiency of the motor and minimize current use, thereby prolonging the life of the battery. Operating the motor at or near its maximum output level is also advantageous in that the motor is able to generate more power at higher rates of rotation.

[0020] In still yet another aspect, the motor comprises a brushless DC motor. Such a motor is preferable because it provides superior cooling and a high power output. Alternatively, a brushed or SR motor may be used.

[0021] In one particular aspect, at least one bearing assembly is coupled to the housing and disposed about the spindle. In this way, the pedals are free to turn when operated by a rider. Use of the bearing assembly is also advantageous in that the crank spindle is used to support the rotor and the planetary gears. Another bearing assembly is preferably disposed between the rotor and the spindle so that rotation of the rotor is generally prevented upon rotation of the spindle by the crank arm. In this way, the rider may pedal the bicycle without turning the motor. Also, this bearing assembly prevents the spindle, and therefore the crank arms, from rotating when the motor is operating.

[0022] The invention further provides an exemplary cycle which comprises a frame having a bottom bracket. At least one wheel is operably coupled to the frame. The bicycle further includes a motor assembly that is disposed within the bottom bracket. Preferably, the motor assembly is constructed to be similar to the motor assembly just described. A first sprocket assembly is coupled to the output driver of the motor assembly such that the sprocket assembly rotates upon rotation of the output driver. A second sprocket assembly is coupled to the wheel, and a chain is coupled between the first sprocket assembly and the second sprocket assembly to rotate the wheel upon rotation of the output driver.

[0023] The disposition of the motor assembly in the bottom bracket is particularly advantageous in that the motor is housed at a low center of mass of the cycle. Advantageously, the motor is not disposed on the wheel which may otherwise add unsprung mass and cause poor suspension and handling and added rotational dynamics. By packaging the motor in the bottoming bracket, the motor is extremely efficient.

[0024] In one particularly preferable aspect, the frame defines a cavity, and at least one battery is housed within the cavity and is electrically coupled to the motor. Preferably, the bicycle frame is constructed of a monocoque design having a hollow center for receiving the battery. In this way, the battery may be mounted in front of the bottom bracket motor and low on the bicycle frame so that the center of mass of the bicycle is low. Further, such a configuration allows the battery to be loaded from the bottom of the bicycle and allows for easy removal. Further, the battery pack and its supports becomes an integral part of the structural strength of the frame when secured within the frame.

[0025] In another aspect, the second sprocket assembly includes multiple gears, and a shifting mechanism is provided to move the chain between the gears. In this way, the

bicycle may be shifted between gears to minimize the required torque. In turn, less current is required so that the life of the battery may be prolonged. Conveniently, a controller may be provided to control actuation of the shifting mechanism based on the rotational wheel speed and the rotational speed of the first sprocket assembly. In this way, the motor may be kept at a maximum speed by shifting the gears. In this manner, the efficiency of the motor is maximized.

[0026] Advantageously, due to the first clutch in the motor, the chain may be shifted between the gears of the second sprocket assembly while the cycle is coasting. This is because the motor is able to turn the front sprocket assembly while the cycle is coasting (and without turning the pedals). Such a feature is advantageous in that the cycle is able to be placed in the appropriate gear which corresponds to the current wheel speed. Further, by the time the rider comes to a stop, the controller has placed the chain in the lowest gear so that starting torque and acceleration may be increased. Similarly, when climbing hills, the controller may be employed to shift down so that more torque may be provided to the rear wheel without using excessive current.

[0027] Conveniently, the shifting mechanism may comprise a derailleur and a cable that is coupled to the derailleur. A stepper motor is provided and has a lead screw to tension the cable based on signals received from the controller. In this way, the cycle may include a standard derailleur which in turn is employed to shift the gears when the cable is moved by the stepper motor upon receipt of signals from the controller.

[0028] In yet another aspect, the cycle includes a throttle to control the speed of the motor. Conveniently, the throttle may comprise a potentiometer that is mounted within a handlebar. The use of an internal potentiometer is particularly advantageous in that it does not interfere with conventional bicycle shift mechanisms which may optionally be employed to shift the chain between the gears.

[0029] In one particular aspect, a swing arm is pivotally coupled to the frame, and the wheel is attached to the swing arm. A suspension mechanism is also disposed between the swing arm and the frame. Such a configuration is made possible by including the motor in the bottom bracket so that it does not interfere with the rear suspension.

[0030] The invention further provides an exemplary method for operating a cycle. According to the method, the cycle has a frame and at least one wheel coupled to the frame. A front sprocket assembly is rotatably coupled to the frame and a rear sprocket assembly is coupled to the wheel. A chain is positioned between the first sprocket assembly and the second sprocket assembly. A motor assembly is provided and has a motor driver to turn the first sprocket assembly and a crank arm to turn the first sprocket assembly. Such a cycle is operated by actuating the motor and optionally turning the crank arm. The motor is engaged to turn the first sprocket assembly if the motor driver is turning faster than the first sprocket assembly. However, if the crank arm is rotated faster than the first sprocket assembly, the crank arm is engaged with the first sprocket assembly. In this way, the rider may choose to have the motor drive the bicycle simply by not turning the crank arm. When the rider wishes to operate the bicycle using human leg power, the rider simply turns the crank arm until the first sprocket assembly is rotating faster than the motor driver. Preferably, when the rider begins to turn the crank arm, such action will not cause the motor to rotate.

[0031] In one particular aspect of the method, a second sprocket assembly includes multiple gears. In this way, the gears are shifted to maintain the motor speed at a near maximum output level while the front sprocket assembly rotates at a rate within the range of the human leg. In this way, the user is able to take over propulsion of the cycle by simply pedaling faster than the motor driver as previously described. Preferably, the motor is operated at a rate in the range from about 1,800 rpm to about 3,600 rpm, and the front sprocket assembly is turned at a rate in the range from about 60 rpm to about 120 rpm.

[0032] In one particularly preferable aspect, the gears are shifted without turning the crank arm. This is made possible by having the motor turn the front sprocket assembly without turning the crank arm.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] **FIG. 1** is a schematic side view of an exemplary electric assist bicycle according to the invention.

[0034] **FIG. 1A** is a cross sectional view of a frame of the bicycle of **FIG. 1** taken along lines A-A.

[0035] **FIG. 1B** is a cross sectional view of an alternative frame for holding a rectangular battery pack.

[0036] **FIG. 2** is an exploded perspective view of an exemplary electric motor assembly of the bicycle of **FIG. 1**.

[0037] **FIG. 3** is a cross-sectional side view of the motor of **FIG. 2**.

[0038] **FIG. 4** is a cross-sectional end view of the motor of **FIG. 3** taken along lines **4-4**.

[0039] **FIG. 5** is a cross-sectional end view of the motor of **FIG. 3** taken along lines **5-5**.

[0040] **FIG. 6** is a cross-sectional side view of a throttle assembly of the bicycle of **FIG. 1** according to the invention.

[0041] **FIG. 6A** is an end view of the throttle assembly of **FIG. 6**.

[0042] **FIG. 7** is a schematic diagram of an exemplary shifting system according to the invention.

[0043] **FIG. 8** is a schematic view of the electronic circuitry employed in the bicycle of **FIG. 1**.

DETAILED DESCRIPTION OF THE SPECIFIC EMBODIMENTS

[0044] The invention provides exemplary electric assisted bicycles as well as motor assemblies for use with such bicycles. Although described primarily in terms of bicycles, it will be appreciated that the principles of the invention may be used with any type of cycle. One important feature of the invention is that it includes a motor/gear reduction assembly that is an integral part of the bicycle bottom bracket and is employed to drive the front sprockets directly by use of a motor driver. By directly driving the front sprockets, the motor may take full advantage of the large range of mechanical gear reductions common to the modern bicycle.

Use of such gear reductions allows for the efficiency of the electric motor and battery to be maximized.

[0045] The electric motors of the invention are configured to use a minimal amount of current. Because the available energy from the battery decreases exponentially with current discharge, the motors of the invention are able to significantly increase the operating time of the batteries. For example, by utilizing the large range of mechanical gear reductions in the modern bicycle, the required torque to drive the bicycle is kept at a minimum. Since motor torque increases linearly with motor current, the invention is able to utilize the mechanical gear reductions to keep torque, and hence the required current, as low as possible.

[0046] Configuration of the bicycles of the invention in this manner provide significant advantages over prior art electric bicycles. For example, bicycles having a motor mounted directly to the rear wheel have only a fixed gear ratio. As such, to obtain a four times increase in torque, the motor current must be increased by four times. The motors of the present invention utilize the 4.5:1 gear ratios of the modern bicycle to produce a four times increase in wheel torque with no increase in current, and no decrease in efficiency.

[0047] Conveniently, the bicycles of the invention may employ the use of a controller or microprocessor to accomplish automatic shifting. In this way, the efficiency of the motor is optimized by constantly shifting to the correct gear to reduce the amount of torque required to drive the bicycle. Further, by utilizing the mechanical gear reductions of the modern bicycle, the motor may be operated near its maximum output level. In this way, the motor is able to operate in its most efficient range to further decrease the amount of motor and battery current losses.

[0048] Another important feature of the bicycles of the invention is that they are able to operate using either electric power or human power, thereby increasing the overall efficiency of the bicycle. One particular feature of the invention is that the motors include a gear reduction assembly that turns the front sprockets at a rate which is comparable to the rate at which a rider would turn the front sprockets. This configuration provides a way to easily change between electric power control and human power control of the bicycle. Conveniently, the motors of the invention may include a clutch mechanism which allows the rider to use human power simply by pedaling faster than the output of the motor. Conversely, when the rider stops pedaling, the motor will be engaged to drive the front sprockets.

[0049] The motors of the invention are preferably configured so that when the rider pedals to turn the front sprockets, such pedaling does not turn the motor. Still another feature of the motors of the invention is that the crank spindles are not rotated by the motor, but only by the rider.

[0050] One particular advantage of utilizing the mechanical gear reductions of the modern bicycle is that such a transmission has been optimized to be extremely efficient. By coupling the motor of the invention with this transmission, great efficiencies are achieved. Further, the motors of the invention are preferably configured so that they are simple in their design to reduce internal frictional losses to further increase the efficiency of the motors. In one exemplary embodiment, both the motor and the gear reduction assembly are concentrically disposed about the crank spindle so that the resulting motor assembly is both simple in its design and efficient. Further, such a design is compact and lightweight to allow it to easily fit within the bottom bracket of the bicycle.

[0051] By utilizing the motors of the present invention with the mechanical gear reductions of the modern bicycle, other advantages are also provided. For example, the bicycles of the invention are able to provide adequate hill climbing ability and acceleration, while other electric bicycles which utilize a motor in the hub or a friction device which couples the motor directly to the tire, have a fixed gear ratio and cannot provide adequate hill climbing ability or acceleration. Moreover, as previously described, the bicycles of the invention are able to minimize torque, and thereby minimize current, when climbing hills and rapidly accelerating.

[0052] By employing the electric motors of the invention to directly turn the front sprockets, the bicycles of the invention may use conventional derailleurs or shifting mechanisms. This is because the rotating front sprockets drive the chain as with a conventional bicycle. Conveniently, the controllers or microprocessors of the bicycles may be coupled to an actuator which shifts the gears to optimize the performance of the bicycle.

[0053] Another feature of the invention is that it may employ the use of a throttle that does not interfere with shifting mechanisms on the handle bar, such as a Shimano type SIS rapid fire lever. Preferably, the throttles include a potentiometer or other sensing device that is internally disposed within the handlebar so that it does not interfere with a conventional shifting mechanism that is coupled to the handle bar. The potentiometers may be actuated by rotating the handle grip or by applying pressure to the grip. As the rider rotates the potentiometer or increases the pressure on the potentiometer, the speed of the bicycle increases.

[0054] Another feature of the bicycles of the invention is that they may be provided with a monocoque frame which includes a cavity which allows the batteries to be held directly in front of the bottom bracket while being disposed as close to the bottom bracket as possible. In this way, the center of gravity in the bicycle is moved to the lowest possible point. In turn, this improves the handling and minimizes the effect of the additional weight of the battery. Further, the battery pack may be secured to the frame to become an integral structural part of the frame. Another advantage of positioning the battery in the frame and including the motor in the bottom bracket is that the motor becomes a part of the swing arm and allows for the use of a rear suspension. The motor may also be attached to the frame (in the bottom bracket) to also allow for the swing arm.

[0055] The bicycles of the invention may optionally include a smart controller to monitor motor current and limit the motor output to provide different levels of efficiency and acceleration in response to rider input. The bicycles may also include a motor controller that allows for high acceleration torque, e.g., up to about 10 times the normal riding torque. Excessive heat generation in the motor may be limited by the smart controller that tapers off the current

during a short programmed time. A thermal sensor may also be mounted in the motor so that the smart controller may monitor the temperature of the motor and adjust the maximum current to prevent overheating of the motor.

[0056] The bicycles of the invention may also employ the use of a torque sensor so that motor torque can be a multiple of the rider torque as required by many national laws governing electric bicycles. Further, the motor controller may be programmed so that the motor does not begin turning until the rider begins turning the pedals at a certain rate of revolution. In this way, the efficiency of the battery may be improved since human power is required to initially accelerate the bicycle.

[0057] In still another feature, the bicycles of the invention may be configured to have the motor voltage modulated with a pulse width modulation. In this way, the motor maximum voltage is kept below the minimum battery voltage so that the top speed of the bicycle does not decrease as battery voltage decreases. Preferably, this will be about 20% of the maximum battery voltage.

[0058] Referring now to **FIG. 1**, an exemplary embodiment of an electric assist bicycle **10** will be described. Bicycle **10** comprises a frame **12** to which a front wheel **14** and a rear wheel **16** are coupled. Also coupled to frame **12** is a handlebar assembly **18** and an adjustable seat **20**. As shown, bicycle **10** is a mountain-type bicycle and includes a front suspension **22** and a rear suspension **24** as is known in the art. However, it will be appreciated that the electric assist features of the invention may be used with essentially any type of bicycle and is not limited to mountain-type bicycles.

[0059] Bicycle **10** further includes a swing arm **26** which is pivotally coupled to frame **12**. Use of swing arm **26** is advantageous in that suspension **24** may more effectively be utilized. At the bottom of swing arm **26** is an electric motor assembly **28**. Motor assembly **28** includes one or more gears which define a front sprocket assembly **30**. Rear wheel **16** includes a plurality of gears defining a second sprocket assembly **31**. As is known in the art, a chain is coupled to the first sprocket assembly and the second sprocket assembly so that as the first sprocket assembly is turned, rear wheel **16** will be turned. Further, associated with front sprocket assembly **30** and rear sprocket assembly **31** are front and rear derailleurs, respectively, for moving the chain between the various gears of the front sprocket assembly and the rear sprocket assembly as is known in the art. Although not shown, front and rear brakes are preferably also included as is known in the art to slow or stop the bicycle. Optionally, actuators for actuating the derailleurs and the brakes may be mounted on handlebar assembly **18**.

[0060] Coupled to front sprocket assembly **30** are a pair of crank arms **32** to which a pair of pedals **34** are coupled as is known in the art. In this way, a rider is able to turn pedals **34** to rotate front sprocket assembly **30**. This then moves the chain to turn rear sprocket assembly **31** and thereby turn the rear wheel **16**.

[0061] As described in greater detail hereinafter, bicycle **10** may be placed in a manual mode where wheel **16** is turned only by operation of pedals **34**. Alternatively, bicycle **10** may be placed in an automatic mode where motor assembly **28** serves to turn rear wheel **16**. Finally, bicycle **10** may be configured so that the rider may choose to have motor assembly **28** operate the bicycle or the user may choose to manually operate the bicycle simply by turning pedals **34** faster than the motor assembly is able to rotate front sprocket assembly **30**.

[0062] As shown, frame **12** is of monocoque design and includes a central cavity for holding a battery pack **36**. Battery pack **36** is electrically coupled to motor assembly **28** and provides the necessary power to operate the motor assembly. Various electronics **38**, including a controller **38*a*** and a battery charger **38*b***, are also disposed within the central cavity of frame **12** and serve to control the various electrical features of the bicycle as described in greater detail hereinafter. Preferably, frame **12** is constructed to have an opening at a bottom end **40** into which battery pack **36** and the electronics **38** are inserted. However, frame **12** may have other openings to provide access to the battery, including the top end and the sides. Wires **47** extend from battery pack **36** to motor assembly **28** so that electrical current may be provided to motor assembly **28**. Electronics **38** also includes battery recharger **38*b*** having a 110 V plug **41** which is held by a power cord retraction mechanism **45**. In this way, plug **41** is retractable to allow plug **41** to conveniently be plugged into a conventional power outlet to recharge battery pack **36**.

[0063] Use of the monocoque design is advantageous in that frame **12** is aesthetically pleasing in appearance. The monocoque design also provides significant structural stability for bicycle **10**. Also, mounting bolts **43** are employed to secure battery pack **36** to frame **12** to increase the structural stability of the bicycle. Further, this design allows battery pack **36** to be placed as low as possible on bicycle **10** so that the center of gravity of bicycle **10** is also low to further increase the stability of bicycle **10**. As previously mentioned, use of the monocoque design allows for the use of swing arm **26** to be pivotally coupled to frame **12** to improve the suspension of bicycle **10**. As still another advantage, the monocoque design provides protection to battery pack **36** from external impact blows and from the environment. Still further, the monocoque design allows more room for the battery pack because there are not frame tubes to interfere with the location of the batteries as with conventional bicycle frames.

[0064] Frame **12** is preferably constructed to have an aerodynamic design. As shown in **FIG. 1A**, battery pack **36** may conveniently be constructed of cylindrical batteries (or cells) **37** to facilitates the aerodynamic design. Use of cylindrical batteries is also advantageous in that cooling spaces are provided around the batteries. It will be appreciated, however, that other battery shapes may be used. For example, as shown in **FIG. 1B**, frame **12'** may have a rectangular interior to hold a rectangular lead acid battery.

[0065] Battery pack **36** is preferably constructed of two or more lead acid type batteries, commercially available from a variety of companies, such as Hawker. Such batteries are typically rated at 12 volts each and are able to deliver 100 amps of current. Such batteries typically weigh about 10.8 lbs. each, and are able to operate about one hour between recharges, assuming the bicycle is operating on level ground. However, it will be appreciated that other battery types may be used. For example, as previously described in connection with **FIG. 1A**, cylindrical batteries, such as NiMH or NiCAD with 1.2 volts/cell and with 30 cells, may also be used. Such a package of 30 cells weighs about 17 lbs.

[0066] Bicycle **10** preferably also includes a display panel that is mounted to handlebar assembly **18**. The display panel includes various displays and switches which are coupled to electronics **38** by a control wire **49** to facilitate operation of the bicycle **10** as described in greater detail hereinafter.

[0067] Referring now to **FIGS. 2 and 3**, construction motor assembly **28** will be described. Although hidden from view, electric motor assembly **28** is disposed within a bottom bracket of swing arm **26**. In this way, the weight of the motor assembly is disposed as low as possible on bicycle **10** to lower its center of gravity. Further, by providing a simple design, the motor assembly is able to fit within the bottom bracket, thereby further enhancing the physical appearance of the bicycle.

[0068] Motor assembly **28** includes a number of components which are coaxial with a main spindle **42**. Further, main spindle **42** is also coaxial with the bottom bracket of the bicycle frame. Main spindle **42** which passes through the entire motor assembly, and is supported by left and right spindle bearings **44** and **46**, respectively. (See **FIG. 3**.) The outside diameter of left spindle bearing **44** is mounted to a main housing **48**. Main housing **48** is employed to house most of the components of the motor assembly and conveniently fits within the bottom bracket of the bicycle as previously described. Right spindle bearing **46** is mounted in an output driver **50**. Coupled to main spindle **42** is a left crank arm **52** and a right crank arm **54**. Crank arms **52** and **54** are coupled to spindle **42** with a tapered positive engagement and by the use of screws **56** which are screwed into threaded slots **58** in main spindle **42**.

[0069] Motor assembly **28** further includes a motor rotor assembly **60** which is mounted to the outside diameter of rotor ball bearings **62**. (See **FIG. 3**.) A motor magnet **64** is fixed to motor rotor assembly **60**. The inner diameter of rotor ball bearings **62** are mounted on spindle **42**. Motor rotor assembly **60** is free to rotate independent of spindle **42** as well as crank arms **52** and **54** which are mounted to spindle **42**. A motor stator **66** is fixed to main housing **48**. A plurality of motor control wires **68** exit through main housing **48**. A circuit board **70** (see **FIG. 3**) having position sensing devices is mounted to a left side of main housing **48**.

[0070] A first planet sun gear **72** is mounted directly to the right side of motor rotor assembly **60**. The outer diameter of first planet sun gear **72** is meshed with three first planet gears **74**. The three first planet gears **74** are mounted on ball bearings **76**. The inner diameter of ball bearings **76** are mounted to shafts **78**. The ends of shaft **78** are mounted to the flange of a second sun gear **80**.

[0071] The outside diameter of second sun gear **80** is meshed with three second planet gears **82**. Second sun gear **80** is supported on spindle **42** by bearings **84**. The outer diameters of first planet gears **74** and second planet gears **82** are meshed with a ring gear **86**. Ring gear **86** is machined directly into main housing **48**. The inner diameters of the second planet gears **82** are mounted to ball bearings **88**. (See **FIG. 3**.) The inner diameter of ball bearings **88** are mounted to shafts **90**. Shafts **90** are attached to a motor output driver ring **92**. Motor output driver ring **92** is supported by the inner diameter of bearing **94** as also shown in **FIG. 4**. The outer diameter of bearing **94** is mounted to a housing end cap **96**.

[0072] Although motor assembly **28** is shown with bearings **94**, it will be appreciated that bearing **94** may be eliminated. In such a case, motor assembly **28** may be modified so that a bearing surface is provided between motor output driver ring **92** and output driver **50** in a manner similar to that described in U.S. Pat. No. 5,570,752, the disclosure of which is herein incorporated by reference.

[0073] Output driver **50** is supported by bearings **98**. The outer diameter of bearings **98** are mounted in housing end cap **96**. Mounted in the right end of output driver **50** is a crank driver ring **100**. Mounted in right crank arm **54** are crank ratchet pawls **102**, as also shown in **FIG. 5**. Ratchet pawls **102** are employed to engage crank driver ring **100** as described in greater detail hereinafter.

[0074] Mounted in the left outside diameter of output driver **50** are a plurality of driver ratchet pawls **104** which are employed to engage motor output with driver ring **92** as described in greater detail hereinafter. The right outside diameter of output driver **50** is attached to a sprocket support **106**. Sprocket support **106** is attached to front drive sprockets **108**.

[0075] Electric motor assembly **28** is advantageous in that it allows bicycle **10** to be operated in three modes. The first mode is pedal only power. The second mode is motor only power, and the third mode is a variable combination of both pedal and motor power. For pedal only power, pedalling of crank arms **52** and **54** by the rider causes the front sprockets **108** to rotate without rotating motor rotor assembly **60**. In this way, significant friction losses to riding the bicycle are eliminated.

[0076] When crank arms **52** and **54** are rotated by the rider, spindle **42** rotates freely in bearings **44** and **46**. Motor rotor assembly **60** does not rotate due to bearings **62**. Further, second sun gears **80** do not rotate because of bearings **84**. The rotation of crank arm **54** causes crank ratchet pawls **102** to engage crank driver ring **100**. This causes output driver **50** to rotate. Sprocket support **106** and sprockets **108** rotate with output driver **50**. The rotational speed of sprockets **108** and crank arms **52** and **54** are the same.

[0077] The rotation of output driver **50** does not cause motor output driver ring **92** to rotate because driver ratchet pawls **104** do not engage motor output driver ring **92** in this direction. Because the output driver **50** is not engaged with motor output driver ring **92**, there is no drag on crank arms **52** and **54** due to motor friction and the bike pedals rotate freely as on a normal non-motorized bicycle.

[0078] For motor only power, the motor drives sprockets **108** but not the crank arms **52** and **54** which may otherwise cause injury to the rider. The rotation speed of sprockets **108** is reduced from the speed of motor rotor assembly **60** by the combined ratio of the two planet gear sets.

[0079] When motor power only is used, a magnetic field in motor stator **66** causes motor rotor assembly **60** to rotate. First sun gear **72** rotates with motor rotor assembly **16**. The rotation of first sun gear **72** causes the first planet gears **74** to rotate. Due to the fixed nature of ring gear **86** and the relationship of the planetary gears, the speed of the second sun gear **80** is reduced by the design ratio. Preferably, the ratio is approximately 5.6 to 1. However, it will be appreciated that other ratios may also be employed. Rotation of second sun gear **80** causes the three second planet gears **82** to rotate in ring gear **86**. This second rotation causes another reduction. Preferably, this reduction is also 5.6 to 1. How-

ever, other reductions may also be employed. Due to the multiplication of gear trains, the overall speed reduction of the motor output driver ring **92** is 31.86 to 1. In other words, the speed of motor output driver ring **92** is reduced to 31.86 times from the speed of motor rotor assembly **60**.

[0080] As motor output driver ring **92** rotates, it engages motor driver ratchet pawls **104** and causes output driver **50** to rotate. As with pedal-only power, the rotation of output driver **50** causes sprockets **108** to rotate. The rotation of output driver **50** does not cause crank arms **52** and **54** or spindle **42** to rotate because crank ratchet pawls **102** do not engage crank driver ring **100** in this direction.

[0081] In the mode having a variable combination of pedal and motor power, power is delivered either by the motor or the rider. If the motor speed is higher than the pedal speed, the motor will cause the bicycle to go faster. However, if the rider increases pedaling speed above the motor speed, the rider will make the bicycle move. Hence, the engagement of output driver **50** depends on the relative speed of the motor and pedals. Whichever is rotated faster will drive the sprockets **108**.

[0082] The invention further provides the ability to recharge the batteries by turning of the pedals. In this option, the motor clutch (motor driver ratchet pawls **104**) may be eliminated and direct contact made between motor output driver ring **92** and output driver **50**. In this manner, when the pedals rotate, the motor also rotates. To eliminate the drag from the motor in pedal only mode, the motor turns just enough to eliminate the drag.

EXAMPLE

[0083] The electric bicycle of **FIG. 1** was theoretically compared to a conventional direct drive electric bike. The electric assist bicycle of the invention was provided with multiple gears. Both bicycles were tested for two situations. First, travel was on level ground at 20 mph. In the second situation, hill climbing was performed at 5 mph. Controller losses are not included in this example and are assumed to be the same for both cases.

[0084] The results of the test are illustrated in Tables 1 and 2 below.

TABLE 1

Comparison at 20 MPH on Flat Ground with 66 in-LB Wheel Torque		
	Direct Drive to Wheel 8:1 Fixed Motor Reduction	Bottom Bracket Motor (Multiple Gear Ratios) 4:1 Final Gear Reduction
Motor Resistance	0.1 ohm	0.1 ohm
Torque Constant	11 in oz/amp	11 in oz/amp
Voltage Constant	8 volts/KRPM	8 volts/KRPM
Battery System Voltage	24 VDC	24 VDC
Motor Terminal Voltage (1)	20.4 Volts	20.4 Volts
Motor Current	12 Amps	12 Amps
Input Power	245 Watts	245 Watts
Output Power	231 Watts	231 Watts
Resistive Losses	14 Watts	14 Watts
Motor Efficiency	94%	94%
Motor Speed	2400 RPM	2400 RPM
Wheel Speed	300 RPM (20 MPH)	300 RPM (20 MPH)

TABLE 1-continued

Comparison at 20 MPH on Flat Ground with 66 in-LB Wheel Torque		
	Direct Drive to Wheel 8:1 Fixed Motor Reduction	Bottom Bracket Motor (Multiple Gear Ratios) 4:1 Final Gear Reduction
Wheel Torque	66 in-LB	66 in-LB
Battery Rating	12 amp-hr	12 amp-hr
Battery Current (1)	10.2 Amps	10.2 Amps
Battery Run Time (2)	50 minutes	50 minutes
Battery Energy	204 watt-hr	204 watt-hr

(1) Based on PWM control of motor speed.
(2) Based on Published Current Vs Run Time Data

[0085] This example illustrates that on level ground, the motor efficiency of both systems is approximately the same, i.e., about 94%. Battery run time is 50 minutes. However, with hill climbing efficiency changes radically. For the bicycle of **FIG. 1**, utilization of the 4:1 gear change reduction, maintains the motor efficiency at 94% with a battery run time of 50 minutes. In comparison, the direct drive bicycle motor efficiency dropped by almost one half to 52%. Further, the battery run time was reduced to almost a third and was only about 20 minutes. In both cases, power output to the rear wheel is kept constant at 231 watts.

[0086] Acceleration of electric motor assembly **28** is preferably accomplished by use of a throttle assembly **110** as illustrated in **FIG. 6**. Conveniently, throttle assembly **110** is coupled to handlebar assembly **18**. Throttle assembly **110** comprises a rubber grip **112** which is disposed about a throttle sleeve **114**. Coupled to throttle sleeve **114** is a planet gear **116** which revolves around a sun gear **118**. Throttle assembly **110** further includes a potentiometer **120** which is rotated when grip **112** is rotated. The potentiometer then sends a signal through wires **122** which are coupled to electronics **38** (see **FIG. 1**) so that electrical current can be supplied to motor assembly **28**.

[0087] Conveniently, a spring **124** is provided to bias grip **112** in a home position so that when released, grip **112** will return to the home position and no electrical current will be supplied to motor assembly **28**. An end cap **126** provides a convenient covering for the internal components. Use of throttle assembly **110** is particularly advantageous in that it has a low profile on handlebar assembly **18** so that other components may be placed on handlebar assembly **18** without interference from throttle assembly **110**.

[0088] The invention further provides an exemplary shift system that allows for automatic shifting on the bicycles of the invention as well as for any standard bicycle. The shift system of the invention allows for automatic shifting on essentially any type of gear system including those having conventional derailleurs, those having internal hub systems, and the like. The shift system of the invention is particularly useful with the bicycles described herein because such bicycles are able to turn the front sprockets without turning the pedals. In this way, the shift system of the invention is able to take advantage of the turning sprockets to constantly shift to the correct or desired gear, even when coasting to a stop when the rider is not pedaling.

[0089] By automatically shifting to the correct gear, the shift system enables the bicycle to be operated at an optimal torque level. With the electric bicycles of the invention, this is advantageous because minimal current is required since torque is optimized. By way of example, one of the problems associated with both regular bicycles and electric bicycles is the need to shift to a lower gear when coasting to a stop sign. Otherwise, the bicycle will be in a high gear when exiting the stop sign, making it difficult to turn the pedals or to operate the motor. A conventional derailleur system requires the chain to be moving for shifting to occur. Because the motor of the invention is able to rotate the front sprockets without rotating the pedals, the bicycle can be shifted while coasting to a stop. Further, the shift system of the invention takes advantage of the moving chain to automatically shift the bicycle to the correct gear depending upon the wheel speed. With the electric bicycle, automatically shifting is further important because the electric bicycle accelerates much faster than a conventional bicycle, requiring the rapid shifting of the gears.

[0090] To optimize efficiency, the electric motors of the invention are preferably kept at maximum speed (which preferably equates to a pedal speed of about 75 rpm). By operating the motor at a maximum rpm, internal heat losses are minimized. Hence, by knowing the gear ratios and the wheel speed, the shift system employs the use of a microprocessor to shift to the correct gear for the current speed. In this way, when the motor is running, the motor speed is kept at a maximum so that motor efficiency is optimized. If the rider adds additional power through the pedals, the microprocessor is configured to shift to a higher gear. Such variables are preferably programmed into the microprocessor to optimize the efficiency for each rider.

[0091] Referring to **FIG. 7**, an exemplary embodiment of a shift system **130** will be described. Shift system **130** includes a linear stepper motor **132** to move a derailleur cable **134**. An exemplary stepper motor that may be used is a Haydon Switch and Instrument stepper motor, part no. 46441-12. Cable **134** is coupled to a derailleur shifting mechanism **136** or an internal hub shifting mechanism as is known in the art. Conveniently, a cable adjuster **138** may be provided to adjust the tension in cable **134**. Stepper motor **132** is electrically coupled to a controller **140** or microprocessor. The amount of movement of stepper motor **132** is based upon the specific type of shifting mechanism and is programmed into controller **140**. The drive for stepper motor **132** is a conventional stepper motor drive as is known in the art. As an alternative to using a stepper or DC motor to move cable **134**, it will be appreciated that other designs may be employed including use of a rotating motor with a gear reduction. Stepper motor **132** further includes a limit switch **142** which is used to define a home position on power up of stepper motor **132**. Limit switch **142** may be a contact type or non-contact type of switch.

[0092] In operation, stepper motor **132** is given a number of pulses by controller **140** to cause the motor to move an exact amount. It will be appreciated that various position sensors may also be employed to determine the position of stepper motor **132**.

[0093] Also coupled to the controller is a wheel speed sensor **144**, a front sprocket speed sensor **146**, and a handle bar interface **148**. With this configuration, controller **140** determines the correct gear by measuring wheel speed with wheel speed sensor **144** and the front sprocket speed with front sprocket speed sensor **146**. Based on the programmed gear ratios, controller **140** selects the correct gear and commands stepper motor **132** to move to the required position. Stepper motor **132** then moves cable **134** causing derailleur shifting mechanism **136** to shift gears. Because motor **132** moves cable **134**, a variety of gear shift mechanisms may be employed, including both internal hub or derailleur type shifting mechanisms. Further, it will be appreciated that system **130** may be employed to shift gears on both the front sprockets and the rear sprockets of the bicycle. Still further, because the electric bicycles of the invention are able to move the chain, even when the rider is coasting, the shift system **130** may be employed to place the bicycle in a low gear when the rider coasts to a lower speed or stops altogether so that the required torque is minimized when the rider begins to accelerate.

[0094] Shift system **130** may be incorporated into bicycle **10** by including the controller in the electronic circuitry stored within frame **12** and by including the stepper motor and appropriate sensors on the bicycle. In this way, bicycle **10** may be operated by using the automatic shifting features of shift system **130**. Conveniently, bicycle **10** may be provided with a standard shifting system, such as a Shimano-type gear shifter, as is known in the art.

[0095] Referring now to **FIG. 8**, the electrical circuitry of bicycle **10** will be described. The circuitry includes a main board controller **150**, a handle bar interface board **152** and a battery charger board **154**. Main controller board is representative of circuitry **38** of **FIG. 1**. The voltage of the system is preferably 24 volts DC but may optionally be 36 or 48 volts DC. Main controller board **150** is coupled to a motor **156** which is representative of motor assembly **28** of **FIG. 1**. Main controller board **150** is also coupled to a throttle controller **158** which is representative of throttle assembly **110** of **FIG. 6**. A headlight highbeam **160** and a headlight lowbeam **162** are also coupled to main controller board **150** so that the bicycle may be provided with lights. Similarly, a tail light **164** is also coupled to main controller board **150**. A rear shift stepper motor **166** is coupled to main controller board **150** and is representative of stepper motor **132** of **FIG. 7**. Optionally, a front shift stepper motor **168** may also be coupled to main controller board **150** to control shifting of the chain on the front gears.

[0096] A battery **170** is further coupled to main controller board **150** and is representative of battery pack **36** of **FIG. 1**. Charger board **154** is also coupled to battery **170**. Charger board **154** is configured so that it may be coupled to a power supply **172**, which for convenience of illustration is shown as a 110 VAC, 15 amp power supply. However, it will be appreciated that other power supplies may be used. Charger board **154** preferably includes a retractable cord which will allow it to be coupled to power supply **172**. Charger board **154** is configured to sense the voltage of battery **170** and will automatically configure itself for such a voltage. Charger board **154** may alternatively be configured to monitor both the temperature and voltage of battery **170**. Further, charger board **154** may charge using either a constant voltage or constant current. Charger board **154** is preferably cooled through a heat sink that is mounted to the frame of the bicycle. A fan may also be used for forced air cooling, if required.

[0097] Also coupled to main controller board **150** is a right turn signal **174** and a left turn signal **176**. A system enable **178** and a cadence **180** are coupled to main controller board **150**. System enable is a safety-type interlock which prevents operation of the bicycle until actuated. Cadence **180** displays

the front sprocket speed. A speed sensor **182** and a torque sensor **184** are also coupled to main controller board **150**. Speed sensor **182** may be employed to facilitate automatic shifting as previously described. Torque sensor **184** may be employed to monitor the torque of the motor so that shifting may occur using the shift system as previously described to keep torque at a minimum.

[0098] Handlebar interface board **152** includes an LCD display **186** and a keypad **188**. Keypad **188** may be employed to control various functions, such as control of headlights **160** and **162**. LCD display **186** may be configured to display various operating parameters such as bicycle speed, current gear, battery life, and the like. An LED power use array **190** is included on handle interface board **152** and is employed to show the amount of current used. The LED array may also be used to show the amount of energy remaining in the battery pack.

[0099] The handlebar interface board **152** may optionally include an auto/manual shift pushbutton interface **192** which is preferably located near the left hand grip of the handlebar. Auto/manual shift **192** is preferably configured to be placed in one of three modes. The first mode is an auto shift mode where shifting is automatic based on wheel speed as previously described. The second mode is manual shift where the rider is responsible for shifting the gear using a conventional shifting mechanism or keypad **188**. The third mode is a manual upshift only, where downshifting is automatic, while the rider has the option to shift up when they desire. In the automatic shift mode, the gear ratios are previously programmed into main controller board **150**. The gears are continuously shifted to keep the front sprocket at the preprogrammed RPM. When coasting, the motor **156** turns the front sprocket when shifting so that the derailleur can shift the gears as previously described.

[0100] A safety interlock **194** is coupled to handlebar interface board **152** and prevents operation of the bicycle until appropriate password information has been entered. For example, safety interlock **194** may require the entry of a numeric key code to activate the bicycle. If tampered with, a horn may be activated. Safety interlock **194** may also include an on/off switch to allow for the bicycle to automatically be turned to the manual mode. Further, safety interlock **194** may be configured to set to a "sleep" mode when not in use for a specified time period, such as for 5 or more minutes.

[0101] A horn, turn signal, high/low beam switch **196** is also coupled to handlebar interface board **152** and allows for operation of the horn, the turn signals, and the headlights. These switches may also be on a separate board located hear the rider's left hand for ease of operation.

[0102] The invention has now been described in detail for purposes of clarity and understanding. However, it will be appreciated that certain changes and modifications may be practiced within the scope of the appended claims.

What is claimed is:

1. An electric motor assembly, comprising:

a housing;

a spindle disposed to rotate in the housing;

a motor comprising a stator coupled to the housing, and a rotor rotatably disposed within the stator such that the rotor is disposed about the spindle;

an output driver; and

a gear system operably coupled to the rotor and the output driver to rotate the output driver upon operation of the motor.

2. A motor assembly as in claim 1, wherein the housing has a central axis, wherein the spindle is aligned with the central axis, wherein the rotor is concentrically disposed about the spindle, and the stator is concentrically disposed about the rotor.

3. A motor assembly as in claim 1, further comprising a sprocket assembly operably coupled to the output driver such that the sprocket assembly rotates upon rotation of the output driver.

4. A motor assembly as in claim 1, wherein the gear system is coupled to a motor driver, and further comprising a first clutch to engage the motor driver with the output driver when the motor driver is rotating faster than the output driver.

5. A motor assembly as in claim 4, further comprising a crank arm coupled to the spindle.

6. A motor assembly as in claim 5, further comprising a second clutch to engage the crank arm with the output driver when the crank arm is rotated faster than the output driver.

7. A motor assembly as in claim 6, wherein the first clutch and the second clutch are coaxially aligned with an axis of the spindle.

8. A motor assembly as in claim 1, wherein the gear system comprises a set of planetary gears to rotate the output driver at a rate of rotation that is less than the motor.

9. A motor assembly as in claim 8, wherein the rate of rotation of the motor is in the range from about 1,800 rpm to about 3,600 rpm, and the rate of rotation of the output driver is in the range from about 60 rpm to about 120 rpm.

10. A motor assembly as in claim 1, wherein the motor comprises a brushless DC motor.

11. A motor assembly as in claim 1, further comprising at least one bearing assembly coupled to the housing and disposed about spindle so as to generally prevent rotation of the spindle by the motor upon operation of the motor.

12. A motor assembly as in claim 5, further comprising a bearing assembly disposed between the rotor and the spindle to generally prevent rotation of the rotor upon rotation of the spindle by the crank arm.

13. A cycle comprising:

a frame having a bottom bracket;

at least one wheel operably coupled to the frame;

a motor assembly disposed within the bottom bracket, the motor assembly comprising a spindle disposed to rotate within the bottom bracket, a motor comprising a stator coupled to the bottom bracket and a rotor rotatably disposed within the stator such that the rotor is disposed about the spindle, an output driver, and a gear system operably coupled to the rotor and the output driver to rotate the output driver upon operation of the motor;

a first sprocket assembly coupled to the output driver such that the sprocket assembly rotates upon rotation of the output driver;

a second sprocket assembly coupled to the wheel; and

a chain coupled to the first sprocket assembly and the second sprocket assembly to rotate the wheel upon rotation of the output driver.

14. A cycle as in claim 13, wherein the frame defines a cavity, and further comprising a battery housed within the cavity, the battery being electrically coupled to the motor.

15. A cycle as in claim 13, wherein the second sprocket assembly includes multiple gears, and further comprising a shifting mechanism to move the chain between the gears and a controller to control actuation of the shifting mechanism based on the rotational wheel speed and the rotational speed of the first sprocket assembly.

16. A cycle as in claim 15, wherein the shifting mechanism comprises a derailleur and a cable coupled to the derailleur, and further comprising a stepper motor having lead screw to tension the cable based on signals received from the controller.

17. A cycle as in claim 15, further comprising a throttle to control the speed of the motor.

18. A cycle as in claim 17, wherein the throttle comprises a potentiometer.

19. A cycle as in claim 13, further comprising a swing arm pivotally coupled to the frame, with the wheel being attached to the swing arm, and a suspension mechanism disposed between the swing arm and the frame, and wherein the motor assembly and the bottom bracket are disposed in the swingarm.

20. A method for operating a cycle, comprising:

providing a cycle having a frame, at least one wheel operably coupled to the frame, a front sprocket assembly rotatably coupled to the frame, rear sprocket assembly coupled to the wheel, a chain coupled between the first sprocket assembly and the second sprocket assembly, a motor assembly having a motor driver operable to turn the first sprocket assembly, and a crank arm operable to turn the first sprocket assembly;

actuating the motor and turning crank arm; and

engaging the motor to turn the first sprocket assembly if the motor driver is turning faster than the first sprocket assembly, and engaging the crank arm with the first sprocket assembly if the crank arm is rotated faster than the first sprocket assembly.

21. A method as in claim 20, wherein the second sprocket assembly includes multiple gears, and further comprising shifting gears so as to maintain motor speed at near a maximum output level while the front sprocket assembly rotates at a rate within the range of the human leg.

22. A method as in claim 21, wherein the motor is operated at a rate in the range from about 1,800 to about 3,600 rpm, and the front sprocket assembly is turned at a rate in the range from about 60 rpm to about 120 rpm.

23. A method as in claim 22, further comprising shifting gears without turning the crank arm.

24. A method as in claim 22, wherein the first sprocket assembly is rotated by the motor without causing the crank arm to rotate.

25. A bicycle frame comprising:

a frame body which is adapted to be coupled to two wheels, and wherein the frame body includes a cavity which is adapted to receive and house at least one battery.

26. A method for operating a cycle, comprising:

providing a cycle having a frame, a front wheel and a rear wheel operably coupled to the frame, a front sprocket assembly rotatably coupled to the frame, rear sprocket assembly coupled to the rear wheel and having multiple gears, a chain coupled between the first sprocket assembly and the second sprocket assembly, a pair of pedals operably coupled to the front sprocket assembly, and an electric motor operably coupled to the front sprocket assembly;

actuating the motor to turn the first sprocket assembly; and

automatically shifting the chain between the gears so as to maintain motor speed at near a maximum output level while the front sprocket assembly rotates at a rate within the range of the human leg.

27. A method for operating a cycle, comprising:

providing a cycle having a frame, a front wheel and a rear wheel operably coupled to the frame, a front sprocket assembly rotatably coupled to the frame, rear sprocket assembly coupled to the rear wheel and having multiple gears, a chain coupled between the first sprocket assembly and the second sprocket assembly, a pair of pedals operably coupled to the front sprocket assembly, and an electric motor operably coupled to the front sprocket assembly;

actuating the motor to turn the first sprocket assembly; and

shifting the chain between the gears without turning the pedals.

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X. RELATED PROCEEDINGS APPENDIX

None